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THE Association was organized in Boston, Mass., on June 21, 1882, with the object of providing its members with means of social intercourse and for the exchange of knowledge pertaining to the construction and management of water works. From an original membership of only TWENTY-SEVEN, its growth has prospered until now it includes the names of over 1000 men. Its membership is divided into six classes, viz.:

A Member shall be an officer or employee of a public or private water works, an engineer, chemist or other person qualified to aid or interested in the advancement of knowledge relative to water works.

An Honorary Member shall be a person of acknowledged eminence in some branch of water supply or of engineering.

A Junior shall be not less than eighteen years nor more than twenty-five years of age, a student or connected with water supply work.

An Associate shall be either a person, firm or corporation engaged in manufacturing or furnishing materials or supplies for the construction or maintenance of water works.

A Corporate Member shall be either a Water Board, Commission, Company or Municipal Corporation.

The initiation fees and annual dues are as follows:

	Initiation Fees		*Annual Dues*
Members	$ 3.00	Members	$ 3.00
Juniors	1.00	Juniors	3.00
Associates	10.00	Associate	25.00
Corporate Members	10.00	Corporate Members	15.00

This Association has at least eight regular meetings each year, of which five are held in Boston, one in northern New England, one in southern New England, and one, the annual convention, held in September or October on such date as the Executive Committee may designate.

METROPOLIS OR MOUNTAIN TOP

PILE SLEEVE OR PIPELINE

LOCK JOINT PIPE COMPANY products for a variety of purposes are offered on a world-wide market. The majestic New York skyline looks down on a bargeload of 144″ Lock Joint Concrete Subaqueous Pipe en route to a metropolitan sewer outfall project, as well as on Lock Joint Concrete Pile Sleeves being installed for the Port Authority's pier construction program.

15,000 feet up on the bleak slopes of the Andes, the installation of 40 miles of Lock Joint Concrete Pressure Pipe made vital water available to the Southern Peru Copper Company's $300,000,000 mining enterprise.

So it is throughout the world. Lock Joint products are bringing fertility to the Negev Desert. Additional water flows to thriving Cape Town through a Lock Joint supply line. Lock Joint transmission and distribution mains as well as sewer lines help meet greatly increased demands in booming Caracas. These are only a few of the thousands of communities at home and abroad served with complete satisfaction by Lock Joint Pipe Company.

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Sales Offices: Chicago, Ill. • Columbia, S. C. • Denver, Col. • Detroit, Mich. • Hartford, Conn.
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Rarely requiring repair or replacement, cast iron pipe performs efficiently, day after day, for over a century.

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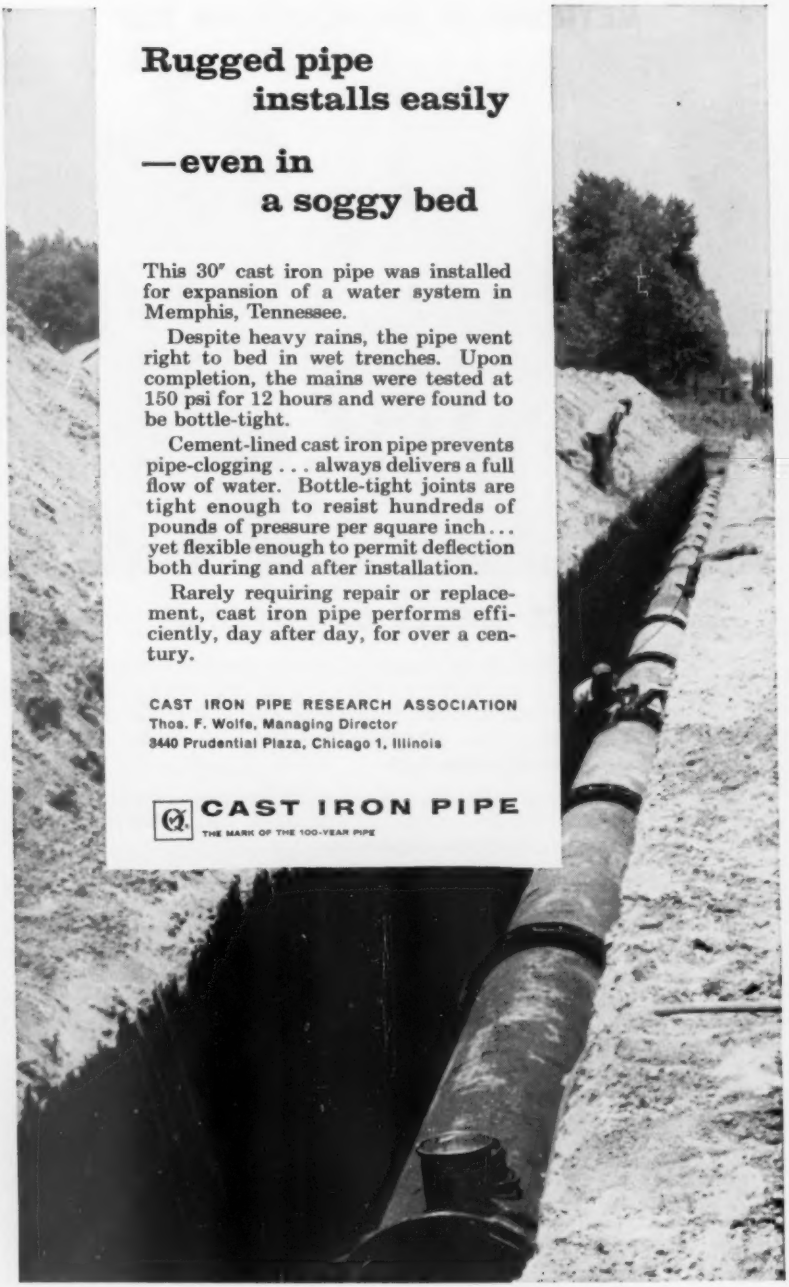

Bulletin

Neptune Reveals 3 Money-Saving Features of Forthcoming New Model 60 Water Meter

Here is a remarkable new meter that makes progress a pleasure – because it protects both your *present and future* meter investment.

The Model 60 has all the advantages of the most modern sealed, magnetically driven register and gear train constructions . . . in a quiet, trouble-free disc meter . . . plus three exclusive new features:

1. The register can be removed, repaired, reset to zero and resealed.
2. Meter registration can be adjusted with change gears . . . vital in reducing repair costs over the years ahead.
3. Protects against unnecessary replacement costs because you can easily repair *minor* damage without having to scrap *major* units.

Older Tridents can be converted and modernized. Both the new register and the new gear train fit standard meters, old and new.

Because of Neptune's standards and dedication to the firm policies of interchangeability and repairability, design of Model 60 has been a more difficult task, and therefore has taken a little more time.

We strongly urge you to wait and see this remarkable new Trident before you buy any sealed meters. (No need to delay your regular Trident purchases, however, because any Trident household meter you buy today can be converted later.)

Trident Model 60 is coming soon . . . watch this magazine for full details.

neptune
TRIDENT WATER METERS

NEPTUNE METER COMPANY

LIQUID METER DIVISION • *47-25 34th St., Long Island City 1, N. Y.*

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ON GUARD IN INDEPENDENCE SQUARE

About 75 feet away from Independence Hall, in the park to the south, stand R. D. Wood Hydrants like sentinels on duty. While their proximity to the Nation's most revered historic monument does not necessarily imply endorsement, we nevertheless like to think of them there, on guard night and day against the fire that could destroy what Gen. Howe saw fit to spare, and Clinton too, in the British occupation. But R. D. Wood Hydrants need no endorsement. For over a century they have shown themselves to be in constant readiness for any emergency. Of simple, ingenious design and rugged construction, R. D. Wood Hydrants are protected against ice and sediment—function smoothly when the engines arrive. There could be no better protection for any community than R. D. Wood Hydrants—and there could be no better protection for the birthplace of the U.S.A.

Conform to A.W.W.A. specifications

R. D. WOOD COMPANY
Established in 1803

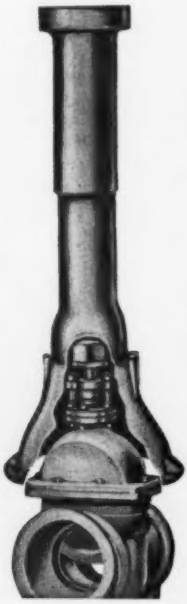
Public Ledger Bldg.
Independence Square
Philadelphia 5, Pa.

Manufacturers of "Sand-Spun" Pipe (centrifugally cast in sand molds)

2 Piece Sliding Type
Adjustable Valve Box

2 1/2 or 3 Inch
Heavy Duty
Service Box

2 1/2 Inch
Service Box



3 Piece Screw Type
Adjustable Valve Box

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2. *Dependability*
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GENUINE BUFFALO
CAST IRON SERVICE, VALVE, ROADWAY AND METER BOXES

MANHOLE FRAMES AND COVERS

CULPEPER, VA.

FOUR reasons why Ford covers offer greater protection and convenience for every meter box installation . . .

1 2 3 4

DOUBLE LID METER BOX COVERS

Designed to provide the utmost in frost protection for pit meters, the "Wabash Cover" has a total depth of 9½ inches. Its extra depth, sloping skirt and 4" dead-air space between inner lid and top lid minimize heat loss from the top of the meter setting.

These covers can be provided in "standard weight" for ordinary service, or "extra heavy," when the lid will be exposed to traffic.

SINGLE LID METER BOX COVERS

Designed for sidewalk or lawn installation, Ford "Type A" covers are made for 15", 18", 20" and 21" meter boxes. Lids are inset.

Lifter Worm lock used on these covers helps speed meter readings. Screw jack action plus automatic attachment of the key to the bolthead make lid removal a simple, clean task.

MONITOR COVER

Designed for use on large tile — where a large lid opening is desirable — "Monitor Covers" consist of 1) a flange casting to fit on the tile, 2) a ring centered in place on the flange by a circular bead, and 3) a top lid with Lifter Worm Lock.

These covers can be used for 1½" and 2" meters . . . or for two or more smaller meters. Lid size permits meter reader to enter setting if necessary.

HINGED LID

Designed for same installations as other single lid covers, "Type X cover" features hinge effect so lid can simply be leaned back instead of lifted off while meter is read.

Simple, ingenious lugs in the frame casting pivot the lid and support it. Thus, if desired, it can also be completely lifted off.

For more information, write . . .

FOR BETTER WATER SERVICES

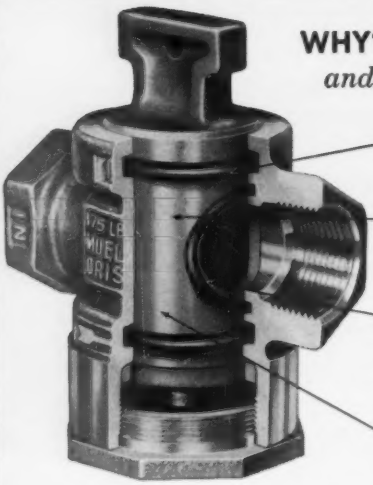
FORD

THE FORD METER BOX COMPANY, INC. Wabash, Indiana

ORISEAL®

by MUELLER®

Introduced one year ago . . .
now recognized as the lifetime curb valve!



WHY? *Lifetime easy turning and positive sealing action!*

Top and Bottom O-rings—provide positive pressure sealing without mechanical means.

Straight, Balanced Pressure Plug—O-rings of equal size at top and bottom eliminate end thrust, contribute to turning ease.

Port O-ring—in specially designed groove in body for maximum support of O-ring to prevent damage. Provides positive pressure seal.

"Teflon"* coated Plug—eliminates necessity of periodic lubrication, prevents "sticking" or "freezing" even after long periods of idleness.

TEST . . . the positive sealing and easy turning qualities of an Oriseal Curb Valve in *your* system. See Your Mueller representative or write for illustrated folder and test report on the Oriseal Curb Valve.

*Registered trademark of the DuPont Company.

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6260

Spotted on this map are some of the places that have been served by the Centriline Process

Chances are that one of your colleagues has rejuvenated some of his city's piping by Centriline reconditioning. Here's your chance to find out.

Briefly, this process smoothly lines piping—**in place**—with cement-mortar, creating a pipe-within-a-pipe. This vastly increases carrying capacity, stops leakage, prevents corrosion and tuberculation, and prolongs pipe life indefinitely. Pressure goes up, pumping cost goes down, and there's no need to disturb traffic to replace mains. Over 6,000,000 feet of piping, from 4" to 144" diameter, have been treated by Centriline.

ASK YOUR NEIGHBOR

Write today for a list of nearby officials whose cities have cut inconvenience and costs with this pipe-saving process. Hear what they have to say about Centriline. Then write or call us. We'll be glad to show you how Centriline can help **you** solve the problems of pipe reconditioning in place.

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Split case or frost proof

lower maintenance

greater accuracy

Offices in principal cities

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NEWARK NEW JERSEY

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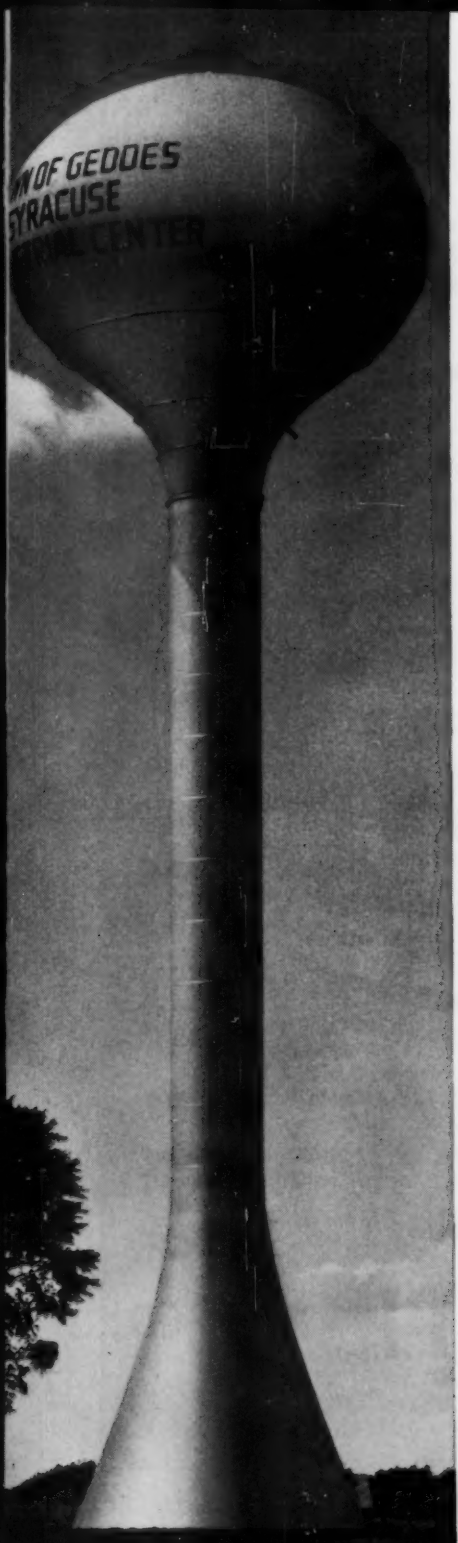

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This 147-foot PDM Pedestal Spheroid—world's highest tank of its type, so far as is known—brings a 500,000-gallon water capacity into balance with Geddes' expanding supply system. Serving the Syracuse industrial area with assurance of ample water facilities for new industries a-coming, the new PDM unit ties in with a 100,000-gallon tank 3 miles away for effective pressure equalization. Is *your* community preparing for increasing water demands?

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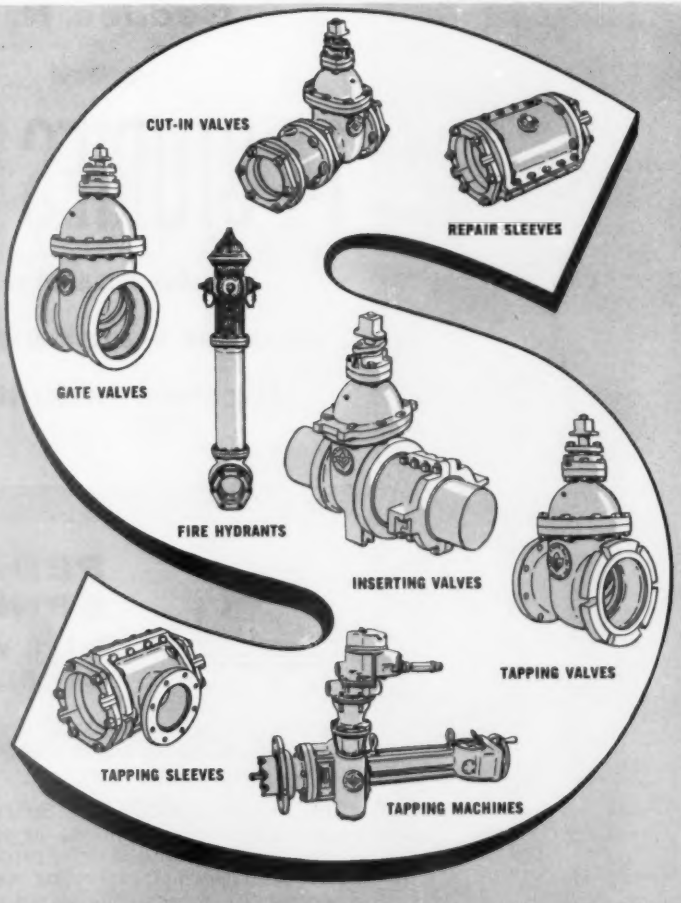

The A. P. Smith Manufacturing Company has served the water and gas utility industry for over 60 years; supplying them with a broad line of superior products including Gate Valves, Fire Hydrants, Tapping Sleeves and Valves and allied equipment.

Smith also designs and builds products for highly specialized services and operating conditions. We solicit your inquiries for standard and special design products.

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THE A. P. SMITH MFG. CO.

SINCE 1896

EAST ORANGE NEW JERSEY

"Only The Best"

For ordering dependable and proven pipe line equipment, consult your latest Pollard Catalog #27.

Included in the #27 Catalog, and displayed on this page, are the M-Scope Transistorized Combination Leak Detector and Pipe Locator, Audio-Scope, Geophone Leak Detectors, T-10 Electronic Box Locator, Aqua Valve Box Locator and Magnetic Dipping Needles for locating service boxes.

Hundreds of water departments all over the country are using Pollard "one order" service. You, too, can enjoy the advantages of ordering from the nation's #1 source for dependable pipe line equipment.

PIPE LINE EQUIPMENT

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PIPE LINE EQUIPMENT

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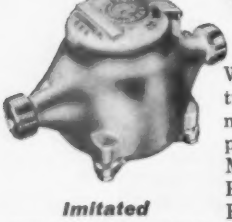
William H. Johnson



Imitated but never equalled

You need only 2 parts!

With Rockwell Sealed Register* meters you need to carry only two parts in your inventory as compared to the large number needed to repair conventional meters. Let our representative prove this to you or write for bulletin W-811. Rockwell Manufacturing Company, Department 164F, Pittsburgh 8, Pennsylvania. In Canada, Rockwell Manufacturing Company of Canada, Ltd., Box 420, Guelph, Ontario.

SEALED REGISTER* METERS
another fine product by
ROCKWELL

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Including TYTON Joints

Either Cement Lined or Tar Coated

Pipe Made in Everett — Centrifugally Cast in Sand Lined Molds in 16′ L/L

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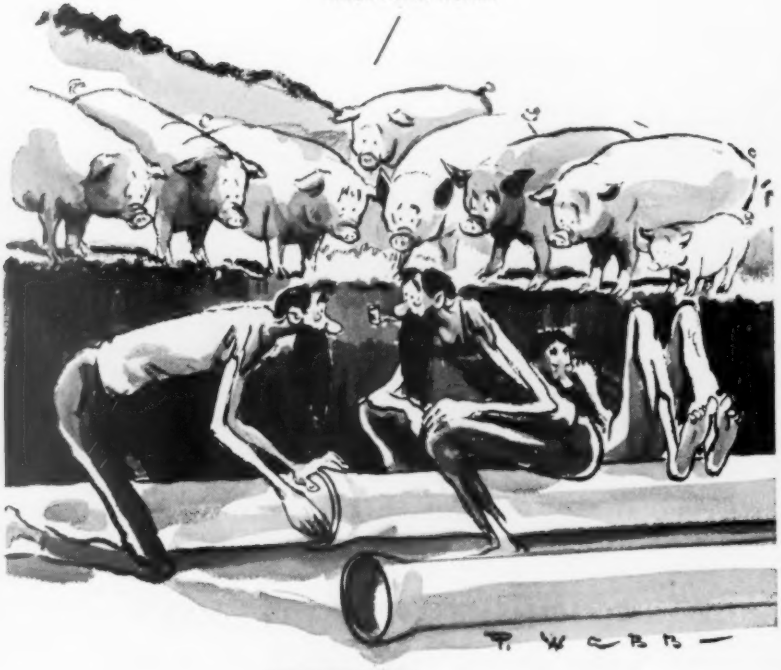
	Ore Mines — Crushed Stone at Dover, N. J.

"Good thing this is simple...
Ah hates bein' watched
when Ah'm workin'"



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PIPE

FOR WATER, SEWERAGE AND

worth looking into!

Fact! Whenever . . . wherever Tyton Joint* pipe goes into the ground it wins more than its share of attention.

And why not? Tyton's so simple . . . so easy to assemble . . . it's a joy to watch. Only one accessory needed—a rubber gasket. No bell holes. No nuts, bolts or caulking equipment. Reduces weather worries too . . . Tyton can be laid in rain or wet trench.

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A Wholly Integrated Producer from Mines and Blast Furnaces to Finished Pipe.

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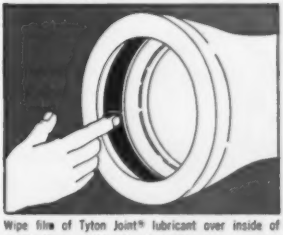
INDUSTRIAL SERVICE CAST IRON

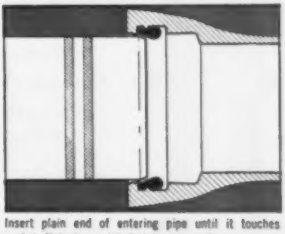
TYTON®

ONLY FOUR SIMPLE ACTIONS

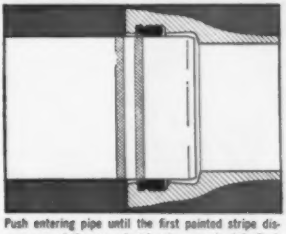
Insert gasket with groove over bead in gasket seat . . . a simple hand operation.



Wipe film of Tyton Joint® lubricant over inside of gasket. Your receiving pipe is ready.



Insert plain end of entering pipe until it touches gasket. Note two painted stripes on end.



Push entering pipe until the first painted stripe disappears and the second stripe is approximately flush with bell face. The joint is sealed . . . bottle-tight, permanently! The job's done . . . . fast, efficiently, economically. Could anything be simpler?

EDDY New Improved Products Meet Modern Needs

EDDY Fire Hydrant

- Improved, streamlined, modernized
- Optional break-flange
- Large diameter barrel
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- Requires no lubrication
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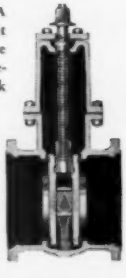
EDDY Gate Valves

In addition to the regular line of EDDY Taper Seat AWWA gate valves, EDDY now offers a newly designed parallel seat AWWA gate valve in sizes through 12 inches. This valve has been specifically engineered to provide long, trouble-free service. Working parts are designed with heavy, thick section and large seating surfaces for dependable operation and improved wearing qualities. The valve has two-point, free-floating wedging for minimum friction and maximum operating ease. Other AWWA gate valves are available through 48 inches.



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Construction began in the middle of April of 1960 and the tank was completed and in service during July of 1960.

After analysing and investigating various types of Storage Tanks, we felt the NATGUN Prestressed Tank best suited our needs, giving long years of service without costly maintenance and frequent interruption of service."

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100% MAINTENANCE-FREE

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- **NO PAINTING**
- **NO DANGEROUS AND TROUBLE-SOME SHUTDOWNS**

The story of how composite, wire-wound prestressed liquid storage tanks can effect substantial savings for you is worth knowing. For full information, write to NATGUN.

NATGUN CORPORATION
101 WEST DEDHAM STREET • BOSTON 18, MASS.

in Badger's *Easy-Read** sealed register

Look into the workings of this Badger Easy-Read magnetic drive meter. Its instrument gearing is smaller, lighter in weight, lower in friction than ever before possible.

Neither water leakage nor corrosion makes demands on the mechanism. Magnets rotate on ball bearings, so the gearing turns freely with practically no resistance. With friction reduced, Badger Easy-Read can maintain accuracy far longer.

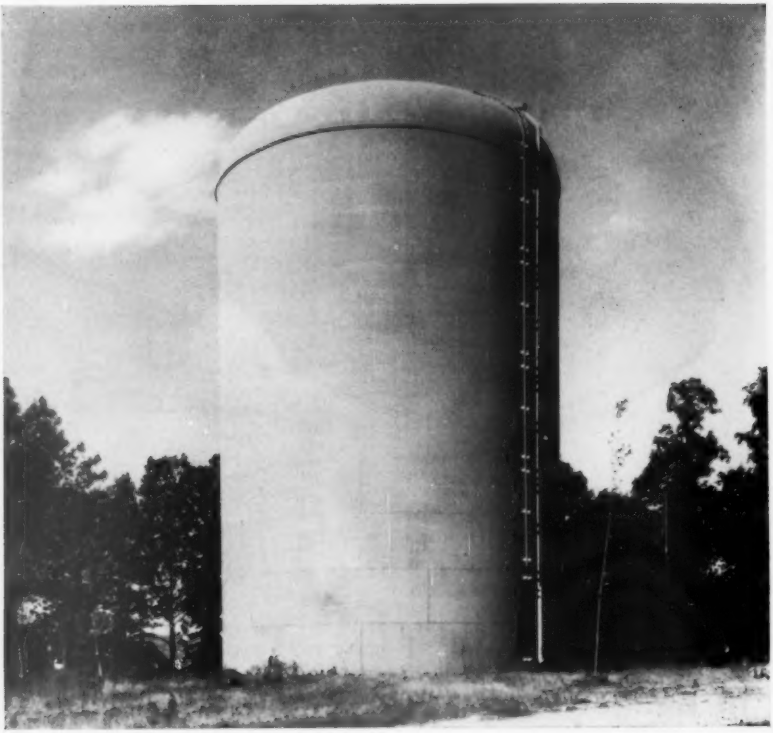
Call or write your Badger representative and ask him to give you a personal demonstration of the new Badger Easy-Read magnetic drive meter.

The new Easy-Read can be ordered in split-case (⅝" thru 2") or frostproof models (⅝" thru 1" x 1¼").

*Trademark

Badger Meter Mfg. Company

4545 West Brown Deer Road • Milwaukee 23, Wisconsin



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TASTE AND ODOR CONTROL FOR PALATABLE WATER

BY ARTHUR F. EVANS*

[*Received Oct. 19, 1960.*]

As the population and industrial capacity of the world increase, the problem of water supply and waste disposal becomes more and more complex. Water sources which were once discarded as unfit for domestic consumption are now being re-examined. The problem is further compounded by the fact that not only do we need more water, but we are increasing the pollution of sources we already are using. This, incidentally, is not a local problem but a world-wide one; Europe has been using less and less attractive sources of water for years and has recently begun experiments in the purification of sea water. The Ruhr in Germany is a further example of the problem. Here the increased demand for drinking water has run hand-in-hand with the increased demand for waste disposal and transportation needs. Thus, the problem of obtaining palatable water is not likely to diminish in the future but rather will become more difficult, unless, of course, a major technological breakthrough is made in water treatment. Prospects for such a breakthrough are non-existent at this time, and it is not wise to wait for such a development. Rather, it is necessary to examine the problems involved as they exist today. Outside of finding a source, the major problem is producing an effluent acceptable to its users. At present it is cheaper to operate one distribution system for each community and distribute the same water for all uses than to have a multi-distribution system with various qualities of water. Water used for gardening, cleaning and other

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domestic needs comes from the same tap as for drinking and cooking. The problem, therefore, is that although only two percent of the water leaving a water treatment plant is actually used for human consumption, all of it must be palatable. As a matter of fact, some plants now spend as much money for controlling tastes and odors as for sterilization.[1]

It is worth noting also that, although the problem of taste and odor control is great and will become greater, it is not new. The chlorination treatment, one of the most significant breakthroughs in water treatment, was resisted bitterly because of the tastes it caused.[2] People, finding objectionable tastes and odors, thought the water to be impure and switched to private sources which were not chlorinated and sometimes were impure.

To explore fully the intricacies of taste and odor control, mention must be made of a few fundamentals, such as: (1) what causes tastes and odors, (2) how they are formed, (3) the relation between tastes and odors, (4) the prevailing measuring systems and, finally, (5) the amount of matter needed to cause taste or odor.

There are two causes of tastes and odors: chemical combinations as dissolved gases, and chemical combinations as dissolved or suspended particles. Either or both are found in water supplies and are caused by the action of materials which have been added to water sources, either by nature (runoff) or by man (sewage and industrial disposal). A further discussion of how tastes and odors are formed is presented later in the paper.

The third fundamental is the relation of taste to odor. Water which has an odor to it will always have a taste. The reason for this is that odors affect the same nerves as tastes, and therefore odors cause tastes.[3] However, not all waters having bad tastes have bad odors. Dissolved minerals will give a taste but no odor.

Another fundamental worthy of mention is the measuring systems used. During the early stages of taste and odor study attempts were made to create a uniform identification system.

1. M. B. Ettinger and F. M. Middleton, "Plant Facilities and Human Factors in Taste and Odor Control," *Journal of the American Water Works Association*, 48:1265-72, October, 1956.
2. Norman J. Howard, "Modern Practices Involved in the Removal of Tastes and Odors by Aeration, Filtration and Other Processes," *Canadian Engineer*, 43:635, December 19, 1952.
3. Thresh, Beale and Suckling, *The Examination of Waters and Water Supplies*, p. 92.

In 1888 Tom Brown, a doctor, published a list of five types of odors and defined each. His hope was that people would be able to communicate and discuss their problems if they had a uniform means of identification. The categories he used were:

1. Earthy—freshly turned soil
2. Straw-like—odor of moist straw (this was the most frequent odor at that time)
3. Mouldy—moist straw which has begun to decompose
4. Musty—advanced mouldiness
5. Disagreeable—anything worse.[4]

Brown's identification system did not catch on but another, although hardly better, did. It is called the relative number method. In this, a number is given to a water sample from zero to five. Zero refers to no odor and five is an offensive odor. The whole system is based on the judgment of the person appraising the sample.

A third method, and the one most often used, is the threshold number system. In this method a sample of odorous water is diluted with distilled or other pure water until the odor is just detectable. Then the total volume is divided by the volume of odorous water and the result is the threshold number. Threshold numbers of two or three are good and under five not usually objectionable. Anything over five may be expected to result in complaints. Sometimes tests are run with both hot and cold samples, since the amount of dissolved gases is considerably different at different temperatures.[5] This, therefore, is one of the shortcomings of the threshold test, i.e., threshold numbers are affected by temperature.

The final fundamental is the amount of matter needed to cause taste and odor. For some substances, as little as two parts per billion is all that is needed, while for most taste producers five parts per million is detectable.[6]

Taste and odor control is a complex problem. A sample of water drawn from a tap may have no odor but when shaken have a distinctive one. The reason for this is that dissolved gases pass off by agitation. Heating the sample may produce a greater

4. Tom Brown, "The Odor and Color of Surface Water," *Tech Quarterly*, 1:10-37, 1888.
5. H. A. Thomas, Jr., "Calculation of Threshold Odor," *Journal of the American Water Works Association*, 35:751-53, June, 1943.
6. Ettinger and Middleton, *op. cit.*, p. 1268.

odor than before but not necessarily the same one.[7] Heating aids chemical combinations, and therefore resulting odors need not be the same as from dissolved gases.

Another reason for complexity is lack of agreement on the amount of odor in a sample. People often can detect odors if aware of their presence or past existence. Threshold numbers, therefore, lose some accuracy due to the human element. Also, it is well known that people have different detection abilities. In 1941, in an article examining the accuracy of the threshold number method, it was concluded that ". . . contrary to widespread opinion, the human sense of smell is totally unreliable as a means for estimating odor concentrations quantitatively with any acceptable degree of accuracy."[8] However, the threshold method is still used more often than any other. Another reason that water treatment is so complex is that odor-causing particles are so small and in such limited numbers that no analytical means has yet been found to measure them. One method that has received some attention is the running of raw water through a clean carbon filter and examining the residue. This has not been done on a large scale, however.[9]

Possibly the major reason for complexity is the inconsistencies encountered. What works at one plant does not at another. Quantities and compositions of industrial wastes are not constant, due to varying rates of production, height of stream, wind, etc. Tastes due to algae and actinomycetes are extremely changeable. Being cyclic, their tastes fluctuate considerably, generally being worse in summer than in winter. Other tastes are seasonal, too. Spring runoffs carry matter which has been preserved through the winter into water sources and consequently cause increased tastes and odors at that time.[10] During the winter, when water sources are covered with ice, putrefaction is increased. It may be noted that back as far as 1882 the cutting of ice was advocated to remedy the ". . . . disagreeable odor which we learn is sometimes noticed during the winter."[11] Within

7. Brown, *op. cit.*, p. 22.
8. R. H. Hulbert and D. Faber, "Studies on the Accuracy of Threshold Values," *Journal of the American Water Works Association*, 33:1958, November, 1941.
9. F. M. Middleton, "Fundamental Studies of Taste and Odor in Water Supplies," *Journal of the American Water Works Association*, 44:1127, December, 1952.
10. "Taste and Odor Problems During Spring Runoff," *Journal of the American Water Works Association*, 44:550, June, 1952.
11. Brown, *op. cit.*, p. 11.

the last fifteen years threshold numbers in excess of five thousand have been recorded.[12]

There are six present-day agents for tastes and odors: (1) algae and actinomycetes, (2) putrefaction, (3) industrial wastes and sewage, (4) dissolved minerals, (5) treatment, and (6) pipes.

Algae and actinomycetes are the oldest causes of tastes and odors. A variety of kinds of both exist, living in warm, slow-moving, shallow water. In their normal growth, algae and actinomycetes secrete oily substances, which may or may not cause tastes depending on their type. Actinomycetes are ray fungi which are closely related to bacteria and fungi. They are ordinarily associated with the soil, although water forms exist. They cause a misty, earthy taste and odor, which is disagreeable to most people. Actinomycetes have been known for a long time, but only in the past ten years has their contribution to taste and odor been realized. Before then it was assumed that algae was the chief culprit. Actinomycetes are particularly offensive, because not only do they impair the quality of water, but also they are retained in the flesh of animals that drink such water. The taste of cattle and poultry as well as by-products (eggs and milk) is affected adversely.[13]

Algae and actinomycete tastes and odors may be removed by a variety of methods. Among the oldest is agitation and aeration. Isolation and use of auxiliary sources is another method used before chemical inventions. Similarly, shifting the draft, both from one area to another and from one height to another, was practiced.[14] A hope expressed by one man in 1887, which dramatizes the oldness of the problem, was ". . . . that in addition to what can be done by removing food from the troublesome algae, additional food which will just suit the palate of the less objectionable could be added and in such case these latter would drive all others out and faithfully guard against any invasion."[15]

12. J. G. Filicky, "Tastes and Odor Control in Indiana," *Journal of the American Water Works Association*, 47:675, July, 1955.
13. J. D. G. Silvey, James C. Russell, David R. Reddon and William C. McCormick, "Actinomycetes and Common Tastes and Odors," *Journal of the American Water Works Association*, 42:1018, November, 1950.
14. Frank E. Hale, "Taste and Odor in New York City's Supplies," *Journal of the American Water Works Association*, 10:829, September, 1923.
15. F. F. Forbes, "The Relative Taste and Odor Imported to Water by Some Algae and Infusoria," *Journal of the New England Water Works Association*, p. 93, December, 1891.

Another method which was practiced extensively in Massachusetts was called stripping. In this method everything, including a layer of soil, was removed from the basin of a reservoir before it was flooded, in an attempt to remove organic matter which the algae needed to live. This was an expensive proposition, and now only stumps above the twenty-foot line, trees, shrubs, buildings and soft material are removed.[16]

Putrefaction was a second problem existing before the twentieth century. Putrefaction refers to organic matter existing in water deficient in dissolved oxygen being reduced by bacterial action rather than oxidation. The usual tastes and odors are due to hydrogen sulphide, a dissolved gas. Putrefaction occurs both in ground and surface waters.

Industrial wastes and sewage were the third cause of tastes and odors in this country. These two man-made causes can affect both ground and surface waters. However, surface waters carry the bulk of the load. In England this also is true, but gas-works wastes and "soakaways" pollute ground-water sources, too.[17] Presently two methods of preventing tastes due to waste disposal are available: prevention of wastes from gaining access to water sources, and removal of tastes caused. At one time in this country the former was advocated; however, the cost was prohibitive and now the burden is split. Wastes are treated, and also water is treated.[18]

The chief problem in industrial wastes is phenols. Although especially prevalent in coke and coal reduction, phenols are met in most industrial areas. The problem in phenols is simple. They combine with chlorine to produce a highly offensive taste and odor. The cure for phenols is not so simple, however, and requires special treatment.

Fourth on the list of causes of taste and odor is dissolved minerals. Occurring both in ground and surface waters (especially ground waters), dissolved minerals are responsible for tastes rather than odors. Two parts per million of iron gives a soapy, inky taste.[19] Iron, manganese and aluminum sulphates taste

16. "Is It Worth While to Strip the Surface Soil from Reservoir Sites?" *Engineering News*, January 3, 1907.
17. Thresh, Beale and Suckling, *op. cit.*, p. 95.
18. *Ibid.*, p. 96.
19. E. A. Sigworth, "Control of Odor and Taste in Water Supplies," *Journal of the American Water Works Association*, 49:1507, December, 1957.

bitter.[20] Detergents high in phosphates provide excellent food for algae, thus increasing taste and odor, while chlorides produce a salty taste.[21]

Finally, water treatments themselves often cause taste and odors. Free chlorine causes both when in excess of one or two parts per million. Besides its effect in the free state, chlorine also combines with many substances to form unattractive compounds. Chlorine combined with phenols causes very bad tastes and odors and, when combined with nitrogen, forms a particularly odorous nitrogen trichloride. Other treatments detrimental to taste control include addition of lime. Lime addition (for water softening and other purposes) can change the intensity of existing odors and have an unfavorable bearing on the efficiency of other taste-removing processes (activated carbon).[22] Delayed filter cleaning will increase tastes,[23] and location of intake pipes will affect the quality of water. Location should depend on prevailing winds, tides and currents and not on the first spot that becomes available.

If water is properly treated, it should be taste-free and odorless. This, however, is not always the case. Distribution systems and even the pipes within people's homes can influence water quality. Organic materials entering the system through breaks or because of incomplete filtration may die from lack of oxygen or be killed by chlorine. Putrefaction results, and tastes and odors develop. Dead ends causing stagnant areas and materials used for packing joints also hinder water quality. Inside homes, warm stagnant water provides a fine breeding place for actinomycetes. In all the above cases flushing with a solution of chlorine is the best cure.

Once the causes of bad tasting water have been discovered the next logical step is removing them. This can be done in a number of ways. Today, because of the complexity of the situation, it is usual to employ a combination of methods, the combination depending on the causes and relative costs. The first method used was aeration, and the first city in this country

20. Thresh, Beale and Suckling, *op. cit.*, p. 100.
21. Ettinger and Middleton, *op. cit.*, p. 1270.
22. W. J. Hassler and Martin Faye, "Influence of Various Chemicals on Palatability of Drinking Water," *Journal of the American Water Works Association*, 36:1185, November, 1944.
23. Thresh, Beale and Suckling, *op. cit.*, p. 98.

to use it was Hoboken, New Jersey, in 1884. Aeration at one time was the only treatment known; today it is seldom used as a primary treatment, but only as a secondary treatment. Years ago it was used both to remove volatile gases and to oxidize organisms and minerals (iron).[24] Today it still is used to remove dissolved gases, such as carbon dioxide and hydrogen sulphide, but in addition, to dechlorinate and add oxygen. Adding oxygen helps prevent water from becoming "flat."

Years ago there were three methods of aerating water; today only one is used. The first was the cascade method, in which water flowed from one container to a second, lower one. The second method was addition of compressed air; the third the forcing of water into the atmosphere through jets. The jet method combined the advantages of large surface area and splashing effect, and was the most efficient. Aeration by the jet method is still used in many parts of the world, usually in combination with other treatments. One place where it can not be used, however, is England. There, fog and heavy industrialization make it impracticable. Probably it could not be used in downtown Los Angeles either.

Potassium permanganate was another method of water treatment used during the latter part of the nineteenth century. It is of minor importance now, although still used in France to disinfect mains in small communities.[25]

Copper sulphate, first used just after the turn of the century, is a method of taste and odor prevention different from any other type. The distinguishing feature of copper sulphate is its employment as an algae destroyer in reservoirs themselves. Being very toxic in solution, copper sulphate inhibits algae growth. The only problem involved with copper sulphate is the temporary addition to tastes from dead algae.[26] A recent advance in this process is the use of frequent small doses instead of one large one. Research shows that more algae are destroyed this way.[27]

Probably the development having the greatest effect on

24. Howard, *op. cit.*, p. 638.
25. Thresh, Beale and Suckling, *op. cit.*, p. 740.
26. William W. Hassler, "The History of Taste and Odor Control," *Journal of the American Water Works Association*, 33:1510, December, 1941.
27. Howard Bailey and James Studley, "Activated Carbon Treatment of an Open Reservoir," *Water and Sewage Works*, 94:219, June, 1947.

taste and odor control was the invention of chlorination. Discovered in 1811 and first used in this country in 1908, chlorination is principally used as a disinfectant.[28] Since its discovery, it has gained almost universal acceptance. There are now two methods of chlorination, marginal and super. Marginal is the application of enough chlorine to secure a residual without completely satisfying the potential chlorine demand.[29] A residual is extremely important because of the need to kill bacteria and algae which find their way into distribution systems.

Chlorination has various effects on the taste and odor of water. In some ways it increases the quality and in others lessens it. Chlorine combines with some substances, which then settle or are filtered out. On the other hand, chlorine accentuates the taste of iodine. Iodoform tastes are caused by a combination of chlorine and only five parts per billion of iodine. Also, if the residual is too high, chlorinous tastes may be noticed when the water is heated or used for cooking. Another problem with chlorine is its readiness to combine with phenols. This is a major problem in industrial waste treatment.

To combat the odors and tastes caused by marginal chlorination, a second method of chlorination, known as superchlorination or break-point chlorination, was developed in 1925. It was noted that as chlorine is added, the residual increases to a point and then decreases rapidly, until it reaches a second point called the break-point. From there the residual increases linearly (see Fig. 1) and is made up entirely of free chlorine. The reason for this pecular action is that chlorine reacts to form unstable taste-causing products which, in the presence of increased concentrations of chlorine, break up. Therefore, the resulting effluent has a chlorine residual free from taste-producing compounds. The advantages of superchlorination include short contact time for disinfection and usefulness with water supplies which fluctuate in chlorine demand.[30]

Disadvantages are found too, however. The taste of excessive free chlorine is undesirable itself, and when this method was first used, it caused a good deal of controversy. John Baylis

28. Hassler, *op. cit.*, p. 1512.
29. Ettinger and Middleton, *op. cit.*, p. 1270.
30. D. B. Williams, "How to Solve Odor Problems in Water Chlorination Practice," *Water and Sewage Works*, 99:358, September, 1952.

in 1930 suggested, since ". . . many waters are polluted with such a variety of compounds, that it may be more advantageous to superchlorinate to break down such compounds as may be attacked by chlorine, and the use of activated carbon for de-chlorination and the removal of certain compounds not attacked by the chlorine."[31] Although this seemed like a reasonable idea, others disagreed. In an article in the *Engineering Journal* in 1931, it was concluded that ". . . . filtration tests should be continued to determine the cost of using activated carbon (as the sole treatment) since there does not appear to be any prospect

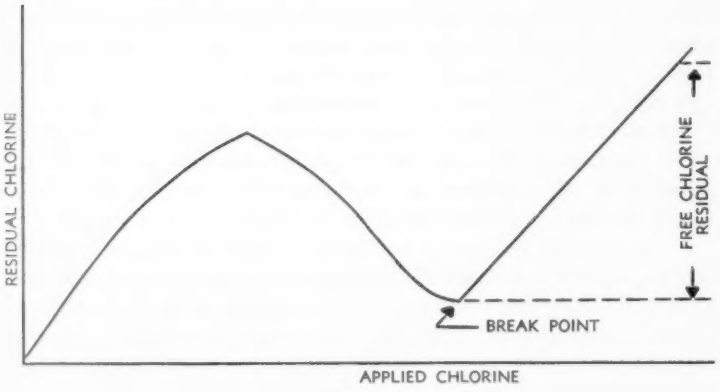

FIG. 1.

of obtaining satisfactory taste removal by superchlorination followed by de-chlorination."[32] Yet, methods for de-chlorination were obtained, and at present superchlorination is commonly used, followed by some process of de-chlorination. For example, a method used in Germany soon after superchlorination was invented was to chlorinate raw water and then filter it through a sand filter. This purified the liquid in so far as removing suspended matter and disease-carrying bodies was concerned. Finally, the water was run through a charcoal filter to remove excess free chlorine. The process was upward filtration, followed

31. John R. Baylis, "Elimination of Taste and Odor in Drinking Water," *Surveyor*, 77:60, January 17, 1930.
32. J. F. Harhom and C. Greaves, "Elimination of Taste in Water Passing through Creosoted Wood Stave Pipe," *Engineering Journal*, 14:515, October, 1931.

by periodic reactivation with steam forced downward.[33] Probably now activated carbon is used instead of charcoal, but the principles are the same.

A second disadvantage to superchlorination which occurred in some water treatment plants was the rise of heavy geranium odors. These odors were attributed to nitrogen trichloride and are formed in waters having a pH of less than four and four-tenths or in alkaline waters having a high nitrogen content. It was not until the development of chloramines that the problem was resolved.

Chloramines refer to a residual made up of compounds of chlorine and ammonia. With chloramine treatment, less chlorine is needed to acquire the same germicidal effect as either super or marginal chlorination.[34] Secondly, chloramines are used for phenol treatment.[35] Discovered only thirty years ago, chloramine treatment gained wide use, principally because of its low cost of installation. The only machine needed for chloramine treatment is a mixing unit. To form chloramines ammonia is added either as a gas or ammonia salt. A reaction then takes place with chlorine to form both mono- and di-chloramines. In this process ammonia is added before the chlorine.[36] If not, the chlorine would react with phenols and could not be easily broken down. The only problem involved with chloramine treatment is that ammonia is a good food for organic growth. Consequently, it must be added only as far ahead of chlorine as necessary to guarantee good mixing.

Other advantages of this method include greater solubility and better residual.[37] A chloramine residual is more stable and remains active longer than a chlorine residual. Further, chlorine is adsorbed by carbon, while chloramines are not; therefore, a chloramine residual can be kept at a safe margin more easily.[38]

A method for the removal of nitrogen trichloride grew out of the chloramine process. In it, chlorination is followed by dechlorination (probably with sulphur dioxide). The nitrogen

33. Baylis, *op. cit.*, p. 59.
34. Hassler, *op. cit.*, p. 1511.
35. A. Prescott Folwell, "Ammonia-Chlorine and Activated Carbon Treatment of Water," *Public Works Magazine*, 63:18, May, 1932.
36. R. P. Irwin, "Taste Control of Water Supplies," *Journal of the American Water Works Association*, 26:1202, September, 1934.
37. Folwell, *op. cit.*, p. 358.
38. Hassler and Faye, *op cit.*, p. 1189.

trichloride will have broken down and formed ammonia, and there will be no taste or odor. However, the chlorine residual will have been removed too. If chlorine is added at this point, nitrogen trichloride will reappear; but if more ammonia is added and then followed by chlorine, chloramines will form.[39]

At about the same time as the chloramine treatment was discovered a second, probably bigger, development occurred. This was the invention of activated carbon. Although the use of charcoal in filters had been known for many years, it had never gained widespread use because charcoal filters had to be cleaned and reactivated too often to be economical. But when activated carbon was produced with its much greater adsorptive powers, a new weapon in water purification came into being. Except for coagulating processes, in which floc actually surrounds suspended matter and either settles or is filtered out, this is the only chemical method that actually removes taste-causing materials. At the present time activated carbon will remove all known causes of tastes and odors, including dissolved gases.

The method by which activated carbon works is adsorption. Here, chemical combinations, electrical in nature, occur between suspended or dissolved particles and molecules on the surface of the carbon. The result is an adhesion of particles to the carbon surface. The first type of activated carbon made was granular and was used in filters. It still is used for that purpose, even though the second type invented, powdered, has greater adsorptive powers due to greater surface area. However, filters with methods of reactivation last longer and have their place in taste and odor control. An example of the long life of carbon filters is a plant in Ohio, operating with the same filters for over twenty years. Every year the carbon is removed and exposed to sunlight for three or four weks. Another place where activated-carbon filters are used is the R. M. S. Queen Elizabeth. Here, water is chlorinated, filtered through sand, and de-chlorinated through carbon filters.[40]

Powdered activated carbon may be used anywhere in the system. It differs from granular in that powdered carbon is usually discarded after use, while granular filters are used for

39. Williams, *op. cit.*, p. 358.
40. Thresh, Beale and Suckling, *op. cit.*, p. 746.

long periods of time. The powdered type could be reactivated too, but costs are usually too high to be worth while. Although powdered carbon may be used anywhere, it is best used on clear water, since there is no reason to use it on suspended matter which would settle out anyway. It is also best to use powdered activated carbon before the filter process, so that it will be removed and not enter the distribution system. A recent development in activated carbon is its use on open reservoirs. In this process copper sulphate is added and then followed by carbon. As yet this process has not been used on a large scale, but on operations so far completed, results have been favorable.[41] A second advantage of activated carbon is that it may be used in any amount. It neither is harmful nor causes tastes. The only inhibiting factor is that unrestricted use becomes expensive, both because of carbon costs and because of reduced filter runs.

The question of whether to use activated carbon or not is affected by the pH. Activated carbon will work four times better at a pH between four and five than between eight and one-half and ten.[42]

The last two methods of taste and odor control are recent ones, chlorine dioxide and ozone. Chlorine dioxide is formed with sodium chlorite and other chlorine solutions. Its chief advantage over other methods is its oxidizing properties; chlorine dioxide oxidizes two and one-half times faster than chlorine.[43] Working in much the same manner as superchlorination, chlorine dioxide breaks up taste- and odor-producing compounds with concentrated chlorine. Advantages due to its oxidizing ability include good manganese removal and aid in forming chlorine residual throughout the distribution system. Chlorine combines with manganese slowly and causes a residue to build on filters, while chlorine dioxide oxidizes much faster, and resulting products settle out.[44] Chlorine dioxide aids creation of a residual because it reacts faster than free chlorine. With chlorine, some slowly-reacting compounds do not react until after they pass through

41. Bailey and Studley, *op. cit.*, p. 220.

42. Thresh, Beale and Suckling, *op. cit.*, p. 746.

43. Harry A. Faber, "A Theory of Taste and Odor Reduction by Chlorine Dioxide," *Journal of the American Water Works Association*, 39:691, July, 1947.

44. C. R. Harlock, "Water Treatment Removes Manganese, Color and Odors," *Public Works Magazine*, 86:78, March, 1955.

the filtration process, but with chlorine dioxide this does not occur.[45]

Ozone, a process just recently brought to this country, is very common in both Canada and Europe.[46] At the present time, the only large installation in this country is in Philadelphia.[47] The major reason for the little attention ozone has received here is the large initial cost of equipment. Each treatment plant creates its own supply of ozone from air and, therefore, the amount of equipment is extensive.[48] The advantages of ozone are the same as for chlorine dioxide.

In conclusion, it may be mentioned that this paper has attempted to give an overall picture of taste and odor control, and point out some of the problems involved. Taste and odor control is a highly complex problem, and conscious effort has been made to keep from bogging down in details and technicalities. Consequently, the paper is incomplete and barely touches the surface of the problem. Finally, it should not be concluded that all possible water treatments have been developed. This is definitely not so. Industrialization will create products and materials and, thus, new problems. It is very possible that water treatment is but in its infancy.

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45. Ettinger and Middleton, *op. cit.*, p. 1269.
46. Irwin, *op. cit.*, p. 1202.
47. Ettinger and Middleton, *op. cit.*, p. 1269.
48. *Ibid*, p. 1270.

AN INTRODUCTORY DISCUSSION OF THE ELEVENTH EDITION OF STANDARD METHODS

BY TSUAN HUA FENG*

[*Presented at Chemists' Session, Nov. 17, 1960.*]

A preview of the eleventh edition of "Standard Methods" (1) by the Journal of the American Water Works Association (2) outlined the revisions, changes and additions of the 1960 edition. The preview serves well for the purpose of having a brief view of the new "Standard Methods."

The eleventh edition begins with a general discussion which includes (a) information relative to selection and maintenance of laboratory apparatus, quality of reagents and available laboratory techniques, (b) illustrative examples of how "significant figures" of a result are calculated and reported, and (c) precision, accuracy and graphical representation of data. With the exception of the introduction of graphical representation of data, the contents are not new but have appeared in introductions to the separate parts of the tenth edition. However, the incorporation of all the basic information under one topic at the opening of a manual is definitely an improvement.

The eleventh edition consists of nine parts, three more than the tenth edition. Two of the additional parts, Part V and Part VI, are new, being devoted respectively to radiologic examination of water and wastes and bioassay procedures of evaluating the toxicity of wastes to fish. The third additional part, Part VIII, deals with iron and sulfur bacteria which were previously included in the part of routine bacteriologic examinations.

New Parts

The procedures and methods included in the part on Radiologic Examination are presented in such a format that the measurement of alpha and beta radioactivity disregarding the sources of radiation, measurements of total radioactive strontium

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in water and measurements of strontium-90 in water can be performed by personnel without much training in radiochemistry.

The bioassay procedures for evaluating the toxicity of wastes to fish are intended to measure the median tolerance limit (TL_m), that is, the concentration of the tested material after being suitably diluted, at which just 50 percent of the fish are able to survive for a specified period of exposure. The key to the test may be the procedures of keeping stocks of test fish remaining in good condition until needed. Some tests to identify the fitness of the fish, after acclimatization and before being used, are needed, especially in the cases where the bioassay is conducted only occasionally.

Changes of Other Parts

Besides the new parts mentioned above, the other parts of the eleventh edition, remaining in the same title and general format, provide many changes for the better. In view of the fact that the group attending the session is more interested in the examination of water in the absence of gross pollution, it is intended to confine the discussion to Part I and Part VII, which deal with physical and chemical examinations of water without gross pollution and bacteriologic examination of water to determine its sanitary quality.

In Part I, the changes may be catalogued as follows:

1. *Rewriting:* The same test procedure is rewritten to make it more expressive and easier to follow and understand.
2. *Name-changing:* The name of a test is changed to avoid misleading and misinterpretation. For instance, in the test of acidity, total acidity and acid acidity are changed to phenolphthalein acidity and methyl orange acidity respectively. In the test of solids residue, dissolved solids and suspended solids are changed to filterable solids and non-filterable solids respectively.
3. *Restoration:* For example, a titrimetric method of the determination of carbon dioxide is restored.
4. *Deletion:* The soap titration for hardness test is deleted.
5. *Accuracy-improving:* Most significant changes belong to this catalogue. To mention a few—(a) Aluminum: It is claimed

that the improved procedure is suitable for the colorimetric determination of aluminum in the presence of iron, phosphate and fluoride which cause analytical results by its tenth edition counterpart lower than the actual values, (b) Chlorine residual: Blank titration is suggested for the iodometric method of chlorine determination to compensate for the liberated iodine from potassium iodine and traces of reducing agents.

6. *New Tests:* New tests are added—For instance, the test for synthetic detergents.

In Part VIII, the following changes are made:

1. *Sampling:* The need for refrigeration of samples during transportation is eliminated.
2. *USPHS Standards of Drinking-water Quality:* If three or more tubes of 10-ml portion are positively confirmed by the fermentation method, or four or more coliform organisms in 100-ml samples are established by direct enumeration method, e.g., the membrane filter technique, immediate remedial action and additional examination are needed.
3. Confidence limits are included in the MPN tables for each of the MPN values.
4. The membrane filter technique becomes an alternative standard method under specified restrictions with the following modifications: (a) 2-hr preliminary incubation eliminated; (b) 100% humidity to be maintained during incubation, and (c) M-Endo medium used as the sole medium.

   It seems to the writer that the present standard procedure of the membrane filter technique should be carried out under strict restriction as related to the upper limits of turbidity and total plate count of bacteria of a sample, after dilution if so required, in terms of the volume of the sample to be filtered. The pooling, compiling and finally evaluating of the data from concerned laboratories in this respect should be done before the membrane filter technique can be effectively applied.
5. Tentative methods for the detection and enumeration of enterococci are introduced. As enterococci die out rapidly in soil and do not increase in numbers in water, a demon-

strated absence of enterococci does not indicate that the water has never been contacted with fecal matter. However, the presence of enterococci positively confirms the fecal origin of a contamination.

References

1. Standard Methods for the Examination of Water and Waste Water. Prepared and published jointly by American Public Health Association, American Water Works Association and Water Pollution Control Federation. 11th Edition (1960).
2. Preview of the Eleventh Edition of Standard Methods. *Journal of AWWA*, 52:1074 (August, 1960).

GRADING WATER SYSTEMS

BY JOHN R. ANDERSON*

[*Read November 17, 1960.*]

All fire insurance rates are predicated upon four basic fundamentals: These are construction, occupancy, exposure and protection. Of the four, protection is probably one of the most difficult to determine as it pertains to many items and applies not only to one risk but to an entire community. Protection refers to the fire defenses provided by a municipality or private organization.

In order to have any degree of uniformity in determining the value of protection, a standard must be established with which existing conditions can be compared. The standard that we use in the New England area is the same as is used throughout the country and is referred to as the National Board of Fire Underwriters Grading Schedule. The schedule was first devised at the turn of the century and has been modified several times, the most recent revision being made in 1956. The New England Fire Insurance Rating Association is responsible for grading medium and small communities, and the National Board of Fire Underwriters is responsible for grading the larger cities.

The schedule provides a negative approach to grading, that is, a community receives no credit for what it has, but is assigned deficiency points for what it should have, but does not. There is a total of 5000 deficiency points allowed. A community receiving 5000 points would have no recognized form of fire protection. On the other hand a community receiving 0 points would have all that is required.

The points of deficiency are subdivided into 500 point groups, providing ten groups in 5000 points. The ten groups are referred to as the National Board classification and are numbered from one to ten. Depending upon the National Board Class, one of six dwelling grades is assigned. The dwelling grades vary from A, the best, to F, the poorest.

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Points of deficiency	Relative class of municipality	Dwelling grade
0–500	First	A
501–1000	Second	A
1001–1500	Third	B
1501–2000	Fourth	B
2001–2500	Fifth	C
2501–3000	Sixth	C
3001–3500	Seventh	D
3501–4000	Eighth	D
4001–4500	Ninth	E
More than 4500	Tenth	F

There are seven major divisions of the schedule; these are: Water Supply, Fire Department, Fire Alarm, Police Department, Fire Prevention, Building Department, Structural Conditions and Climatic Conditions.

The water supply is the most important section and is allotted 1700 points, which amounts to thirty-four percent of the entire schedule.

There are thirty-two divisions of the water supply section, each with many subdivisions.

First the organization and administration of the department is considered. Here we are looking for effective administration, long tenure of office for the superintendent and key personnel, with removal from office only after a public hearing. It is only through tenure of office provisions that a superintendent can properly plan ahead and carry out long range plans, free from political interference.

Plans and records of the water system are taken into consideration. The schedule calls for plans of the source of supply, safe yield, daily observation of drawdown in wells or levels of water in surface supplies. A distribution plan should be provided, maintained to date, indicating the location and size of all mains, gates and hydrants in the system. Sectionals should also be available if necessary to indicate important details. Records of maximum and average consumption, determined by meters, are especially valuable, also records of pressures in the system are helpful. Water level in storage is also a requirement.

We are also looking for maintenance records of hydrants, hydrant inspections, gate-valve inspections, along with records of maintenance of plant equipment and of all repairs.

We believe that the keeping of proper records is especially valuable in the operation of any water system. How many businesses would bury thousands of dollars in the ground and not keep a record of where to find it? How can we in the water works business bury pipe and fittings in the ground and not prepare a plan as to where it is or how it can be found. The keeping of records is essential for the operation of any business. Many places we have visited, we have marvelled at the superintendent who is able to put his foot on every gate valve in the system and knows without a shadow of a doubt the size and location of all the pipe in the system. This is wonderful, but none of us is going to last forever, and what is going to happen to all that information that is in his head when he is gone?

Any water department or company should have sufficient equipment and emergency crews that can quickly be assembled with all the necessary equipment to take care of leaks, breaks and other malfunctions of the water system. There should be spare hydrants, valves, repair sleeves and various sizes of spare pipe that can be quickly utilized. The situation we find most prevalent in the smaller departments is that at the end of the working day, the shop is closed and every one goes home, with no one delegated to receive emergency calls. I shall always recall talking to a superintendent in a small system and asking if he had any earth moving equipment. He replied that he had a pick, a hand shovel and a rake and that he personally owned the pick and shovel. The town had provided the rake. Now a situation such as this is utterly ridiculous. I am firmly convinced that a water system should be properly maintained and advanced or it should not be in existence.

One of the most misunderstood requirements of the schedule is one that specifies that the superintendent or some responsible member of the water department respond to all serious fires. We do not ask the superintendent or one of his men to fight the fire; we do, however, ask that the superintendent or his man be at the scene to advise the fire department properly on how to

get the most out of the system. By doing this, you also protect your own interest, as many times following a large fire some one generally makes the statement that there was insufficient water to combat the fire effectively.

The grading schedule is based on two basic fundamentals: adequacy and reliability. If a system is adequate in every respect and unreliable, it is not worth very much, on the other hand if a system is reliable but not adequate, it is not much better—so adequacy and reliability are inter-related through the entire schedule.

The first part of our study of a water system concerns adequacy of all parts of the system, source of supply, pumping capacity, storage facilities, pipe sizes. These should all be adequate to supply maximum daily consumption plus required fire flow. Fire flow, in theory, is the rate of water flow necessary to combat any type of fire in a community and bring about its extinguishment. Frankly there is no way to my knowledge of accurately predicting the rate and quantity of water that will be used at a fire. We try to approximate the rate and quantity that might be used or required by examining the type of construction, closeness of building construction, occupancy of various sections of the town. Generally we find the area of a municipality that require the greatest fire flow to be the principal business district. There have been formulas devised for determining fire flow and these have been expressed as a function of population of the town, but this is not a logical approach in all cases, as we find many bedroom towns, nearby cities that have large populations, but few, if any, heavily built areas. In communities such as these to suggest fire flow on the basis of population would be ridiculous.

A water system, to be adequate, should be capable of delivering water at a maximum daily rate plus the superimposed fire flow. For example: if maximum consumption in a system was 4.00 MGD and required fire flow was 3000 GPM or 4.32 MGD, the system to be adequate should deliver 8.32 MGD at all times of year.

A water system should also be reliable. First we consider the reliability of the source of supply on the basis of records kept or on the basis of observation and experience of the source

through the years. If we find the yield of the sources of supply to be below maximum consumption during the summer of each year, and water in storage being depleted, a deficiency will be assigned, depending upon the severity and frequency of the condition.

In considering the reliability of pumping capacity, there should be sufficient capacity so that the system will be able to supply maximum consumption and fire flow, with first, the largest, and then the second largest pumps being taken out of service.

In the same manner, we consider a single power failure anywhere in the town's electric distribution system that would have the worst effect upon the power supply to pumping stations. If such a power failure results in the inability of the pumping equipment to operate, a deficiency will apply, depending upon the ability of the system to again deliver maximum consumption, plus required fire flow. Of course, the deficiency could be eliminated by providing an auxiliary means of operating the pumping equipment or duplicating the electric supply, or by providing storage in the system.

We also consider the arrangement, operation and reliability of plant equipment; is the equipment in good condition, properly maintained and arranged? Are regular inspections made of important valves? I recall in one town where the pumps were discharging through a check valve and a long force main to a stand-pipe. Every time the pump shut off, there was a water hammer so bad the entire pumping station vibrated. Naturally this situation cannot go on forever without causing damage. Are the altitude valves and pressure regulating valves properly maintained and inspected periodically, with proper records being kept? This is one of the requirements of the schedule.

The construction of the pumping station is considered and any hazardous conditions that exist in the station that might cause or spread fire rapidly. If such a situation exists in a pumping station, we assign a deficiency on the basis of that station being out of service and the ability of the remainder of the system to deliver maximum consumption plus fire flow.

Regarding the reliability of the distribution system, supply

mains and force mains, we consider the greatest effect that a single break in the pipe line network would have on the ability of the system to deliver maximum consumption, plus required fire flow. If this requirement cannot be met, then a deficiency will apply.

We also try to analyze the strength of the distribution system. This is done by making hydrant flow tests at various points in the system. These points are selected, depending upon their location in the system and also because of the construction and occupancy of built up areas. Fire flow tests are generally made by flowing water from one hydrant and determining the rate of flow by pitot tube. A second hydrant is used to measure static pressure, and when water is being discharged from the first hydrant, to measure residual pressure.

Where there is a good supply of water available, it is not necessary that we open the flow hydrant fully to make the test, in fact if we did this, we would have difficulty in reading the gauge on the pitot tube. However, in areas where there is very little water available, it is necessary to attach a small diameter nozzle to the hydrant outlet to measure velocity and open the hydrant fully. Another important item deals with the quality and condition of the pipe in the distribution system. Fortunately it has been our experience that either most of the thin-walled pipe is being removed or at least plans have been formulated for its removal. However, there is a serious problem that exists in many systems regarding the interior condition or carrying capacity of pipe. You all know, far more than I, the effects of tuberculation and incrustation of pipe. In many towns we have visited we find the system is capable of discharging only one third to one half the quantity that was available ten to fifteen years previous. In a town not too far from Boston, we found that a 12″ pipe had a "C" of 30; 10″ pipe had a "C" of 26. This situation had existed for at least ten years and would have gone undiscovered except for the flow tests we made, or until a large fire took place where large amounts of water would be needed, and then it would have been too late to do anything about it.

This is not only a problem facing the fire department, but as you all know adds to the cost of pumping operations, because

the increased friction loss in pipe results in higher dynamic heads.

The spacing of gate valves is also considered; the schedule calls for a sufficient number of gates that no single case or accident or breakage will necessitate shutting down a length of pipe greater than five hundred feet in high-value areas or greater than eight hundred feet in other sections. Gate valves should be inspected yearly and large valves more frequently. Suitable records of inspections and repairs should be maintained.

The last section of the schedule deals with the number, distribution, and condition of hydrants. The distribution of hydrants is determined by the required fire flow and the spacing of hydrants is determined by the physical layout of the town or district to be protected.

All hydrants should be inspected semi-annually and after use. This should be done in the Spring and Fall of each year, and inspections should also be made daily in high value districts during prolonged periods of severe cold weather. Suitable records of inspections and repairs should be maintained. All hydrants should be connected to the street main with a branch connection at least 6″ in diameter, and all branch connections should be equipped with a gate valve.

These are some of the more important items that are taken into consideration in the grading of water systems. There are, of course, many details that I have not discussed that would be evaluated during a survey, but the importance of these would vary depending upon the type of system involved.

In conclusion, our aims are identical to the water-works people, fire chiefs and to the individual citizen; namely, to reduce the number of lives lost and the destruction caused by fire. The Rating Association welcomes the opportunty to assist any municipality, group, or individual in any problem concerning fire protection. With reference to municipalities, many times deficiency points can be eliminated by discussing the problem with us before action is taken.

Fire protection, like any business, is discovering new and more efficient ways of doing business. It is through continuing our education and broadening our experience that we will be able to bring about the desired results.

STUDY OF COLOR AND IRON REMOVAL BY MEANS OF PILOT PLANT AT AMESBURY

BY ROBERT A. McCRACKEN*

[*Read November 17, 1960.*]

The present water supply for the town of Amesbury is obtained from a tubular well field in the valley of the Powow River at a location known as Rings Corner. Water was first turned into the system from this source on February 15, 1911. By 1926, the iron content of the wells had increased to such an extent that it was necessary to construct treatment works at the Rings Corner location to remove the iron and manganese from the water before pumping it to the distribution system.

The wells are located on either bank of the Powow river and range both easterly and westerly of Newton Road. The well field consists of about 150 2½-inch tubular wells, varying in depth from 30 to 50 feet, of which approximately 80 are said to be active. The safe yield of this field has been estimated to be about 1.3 million gallons per day.

The iron removal plant, designed by Weston and Sampson, Consulting Engineers of Boston, was first put into operation on February 1, 1927. The works, designed to treat up to 1.5 million gallons per day, were completed at a cost of $85,000. The adequacy of the plant for treating the water available at the time is shown by the fact that for the first 6 years of its operation (1927-1932 inclusive) when the average iron content of the raw water was 5.71 parts per million, the average iron content of the treated water was 0.13 parts per million, a reduction of about 98%.

The iron removal plant provides four distinct unit operations, consisting of aeration, filtration through a coke bed, plain sedimentation and slow sand filtration. In addition prechlorination, post-chlorination, and soda ash can be utilized.

The town is provided with two distribution reservoirs in

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addition to the 250,000-gallon clear water reservoir at the pumping station; these are referred to as the high pressure and low pressure reservoirs respectively, and each has a capacity of 1,000,000 gallons. Both are located on Powow Hill. The low pressure reservoir is under ground and of covered concrete construction. The high pressure reservoir is of open construction.

The water from the wells at Rings Corner is characterized by a large amount of iron in the soluble ferrous state. Upon contact with the oxygen in the air this iron becomes oxidized to the insoluble ferric state. This change results in a greatly increased amount of color and turbidity. If a sample of water is drawn from the pumps and allowed to stand, it can be clearly seen how the raw water quality progressively deteriorates due to the continuing oxidation of the ferrous iron. The significance of this lies in the fact that if the iron removal process is unsuccessful in removing the iron before the water is delivered to the distribution system, the gradual increase in color and turbidity occurs within the system, and the consumer receives a highly colored water. Common complaints about a water supply containing too much iron are concerned with rusty or "red water," staining of laundry, staining of cooking utensils, staining of plumbing fixtures and the imparting of disagreeable tastes to cooked foods. A further effect often concerns the growth of "iron bacteria," which may become established in the distribution mains of systems carrying waters rich in iron. Frequently, these organisms will grow so prolifically as to cause serious trouble in the distribution system, and in addition, as the organisms die they decompose and impart a disagreeable taste and odor to the water.

The Rings Corner Pumping Station and well field are located on the banks of the Powow River, and it is understood that the town has certain rights to the flow of the river. Accordingly, the possibility of the river water's being utilized for the public supply, possibly as an emergency source, was recognized in this investigation, and analyses were made to determine certain natural characteristics of this water. The river water is highly colored by organic matter, principally vegetable materials, such as leaves, peat and trees, in contrast to the color of the well water which is principally due to the iron compounds. A considerable amount of sediment and turbidity was noted in

the river, but this may be expected in a flowing body of water, especially after periods of heavy precipitation and rapid runoff. A pronounced "earthy" odor was observed, but the amount of organic matter and the chloride content are comparable to those found in some public water supplies obtained from surface sources. The water is soft, low in alkalinity and has a pH slightly below 7.0. It contains no manganese and relatively little iron compared to the ground water supply.

The question naturally arises as to why, if the present iron removal plant was so successful during its inception (average of 98% removal for the first 6 years of operation), its efficiency has deteriorated to the point where filter runs are short, consumer complaints are not uncommon and the iron removal plant may generally be said to be doing an unsatisfactory job at certain times.

It should be recognized that the effective removal of iron and manganese by plain sedimentation and slow sand filtration, as presently employed in Amesbury, is limited to water containing considerable alkalinity, little organic matter and relatively large amounts of iron and manganese. If it is agreed that an excessive amount of organic matter, probably of surface origin, is getting into the well water supply at certain times of the year, it can be appreciated that the iron removal plant is being expected to do a job for which it was not designed.

It is the opinion of the firm of consulting engineers which originally designed the iron removal plant that the ability of the plant to produce a good effluent at some times and not at others is due to the changing character of the raw water and its variable content of organic matter.

An analysis of data regarding the population and water consumption of Amesbury since 1905 shows that while the population has increased only 26% in this period, the average daily water consumption has increased 76%. Also the per capita consumption of water in Amesbury is still relatively low in comparison to comparable communities.

During the past few years, the town has undertaken an extensive program of test well drilling in an attempt to find suitable new sources of ground water supply. By and large the results have been disappointing, those sites having a promising

quantity being deficient in quality and those sites yielding water of good quality having a restricted quantity. At least one site was found, however, in the Lake Attitash area which seems to warrant further investigation.

Three general conclusions were drawn from the multitude of data studied:

(1) The future water needs of the town will in all likelihood continue to grow until they finally exceed the capacity of the existing works, making some sort of expansion imperative.

(2) Any acceptable new source of ground water supply will probably be in the Rings Corner—Lake Attitash area.

(3) The present iron removal plant is inadequate to treat the water supplied to it at certain times of the year.

Description of the Pilot Plant

The water treatment pilot plant, owned and operated by the Division of Sanitary Engineering of the Massachusetts Department of Public Health, as used in the Amesbury investigation, consists of five main units. These include a flow measurement device, chemical feeding apparatus, a flocculation tank, a sedimentation basin and a rapid sand filter column. With this pilot plant it is possible to duplicate most conditions and processes found in conventional water treatment plants.

Raw water for the Amesbury supply is drawn from the wells by means of 2 8-inch, 1400-gallon-per-minute, Fairbanks-Morse low-lift pumps, each operated on alternate weeks. Taps were placed on the discharge side of both pumps and connected in series with appropriate gate valves, so that regardless of which pump was operating a continuous flow of raw water to the pilot plant was assured.

Flow through the pilot plant was measured by means of a Fischer-Porter flow meter. This flow meter has a maximum capacity of 4.7 gallons per minute, and the scale on the face of the meter reads in percentages of this amount of flow.

Chemicals were fed to the pilot plant by two pumps. One is a positive-displacement rotary-drum type, known as the "Harvard Pump." This pump is capable of very slow speeds and is able to pump very small, accurately measured amounts of liquid chemical solutions. The second pump, used when it be-

came necessary to feed larger quantities of chemicals per unit of time than the "Harvard Pump" was capable of delivering, was a positive-displacement diaphragm type.

The discharge lines from both of these feed pumps were connected to small taps in the raw water supply lines to the pilot plant. After each tap a partially closed gate valve produced turbulence and helped mix the chemical and the water. Immediately after the last tap for chemical injection a series of sharp bends were introduced into the pipe by means of 90° elbows. This caused rapid and repeated changes of direction in the flow of the water, introduced turbulence and provided for the further flash mixing of chemicals and water.

The flocculator consisted of a plexiglas tank, 5 feet long, 2 feet wide and 2 feet high. This tank is provided with tapped ¾-inch holes to provide for the influent entering one end near the center bottom and effluent leaving at the upper center of the opposite end. The unit is equipped with a longitudinal paddle-wheel having four arms, to each of which are attached two wooden slats. The paddle is turned by means of a chain and a sprocket drive. Power is supplied by means of a ¼-H.P. motor connected to a reducing gear box drive.

The sedimentation tank is a plexiglas unit 5 feet by 3 feet, 9 inches in size. It has a radically sloping bottom, rising from 18 inches in depth at the inlet end to 9 inches in depth at the outlet end. Flocculated water enters through a ¾-inch hole located in the side of the inlet device. The influent end is equipped with an overhanging rectangular section, designed to distribute the incoming flocculated water over the entire width of the sedimentation tank. A plexiglas baffle plate was located 16 inches from the influent end of the tank. The water leaves the sedimentation tank by flowing over a multiple V-notched metal weir into a collecting trough. From this trough it may be either pumped onto the sand filter or piped to waste.

The filter unit consists of a plexiglas tube, 5 feet in length and 2 inches in inside diameter. The bottom of the tube contains a wire screen, which supports a column of sand, which may be varied as to composition and depth. A portion of the flow from the sedimentation tank may be diverted through a small centrifugal pump and introduced onto the filter column through a

fitting at the top. Prior to entering the sand filter the water may be measured by means of a Fischer-Porter flow meter. Filtered water is piped from the bottom of the filter and collected for analysis. The piping is so arranged that it is possible to reverse the normal flow of water and backwash the sand column very readily in a manner similar to that used in actual rapid sand filter plants.

It was recognized at the beginning of the study that in order successfully to conclude this experiment with meaningful data that could be easily correlated and interpreted, it would be necessary to proceed with some orderly and logical approach to the problem. Accordingly it was decided that jar tests would be first used to determine appropriate chemical treatments and estimate dosages. An attempt would then be made to reproduce the most promising of these jar tests, which are necessarily batch-type treatments, with the larger continuous-flow system represented by the pilot plant. If comparable results could be obtained through these two systems, the designer of a full-scale prototype plant should have adequate assurance that any given treatment would work satisfactorily.

The jar tests noted in this report were made at the Lawrence Experiment Station. Raw water samples were, in general, collected in the morning and taken directly to the laboratory for analysis. The treatments yielding the most promising results in the jar tests were then tried in the pilot plant.

The chemical most commonly used in this area for coagulation is aluminum sulphate, which is sometimes called "filter alum" or simply "alum." When alum is employed as a coagulant in water treatment a reaction takes place with the alkalinity of the water (either naturally occurring or artificially added as lime or soda ash) which results in the formation of a floc of hydroxide of aluminum. This hydroxide of aluminum is an insoluble compound, and consequently the floc will settle out in the sedimentation tank and may entrap and carry down with it certain impurities.

Extensive jar tests conducted at the Lawrence Experiment Station indicated that the following results could be obtained by using alum as the coagulant:

(1) With a dosage of three grains per gallon of filter alum a very good floc was formed, and color was lowered to 20 parts per million and iron to 0.3 parts per million. Higher dosages of alum did not increase the color removal and only served to decrease the pH and increase the amount of residual iron.

(2) Slightly better results were obtained by using liquid alum. With a dosage of 0.3 milliliter per liter of liquid alum, color was reduced to 12 parts per million, iron to 0.2 parts per million, and a very good floc was formed.

Unfortunately it was not found possible to duplicate these laboratory results in the pilot plant. In the beginning the difficulties were of a mechanical nature, having to do with the manner of injecting the necessary quantities of chemicals and adjusting the speed of the flocculator paddles. However, even after these problems were resolved it was not found possible to produce a sufficiently large floc in the pilot plant to perform the function of entrapping and removing the color and iron. In the series of pilot plant runs using filter alum and liquid alum, color and iron could not be brought down into range where this type of treatment could be considered successful or acceptable.

Inasmuch as the next most common coagulant to alum is the iron salts, the second phase of the investigation was directed toward trying to devise a way in which the natural iron content of the water could be used as a coagulant. It was found that application of a reasonable amount of chlorine alone (applied as an HTH or calcium hypochlorite solution) was sufficient to oxidize the iron from the ferrous to the ferric state. With flocculation some of the iron would then settle out as insoluble ferric hydroxide. The HTH solution had the effect of depressing the already low pH even lower, so that the pH of the effluent would have to be adjusted upward by post-liming or similar treatment to inhibit corrosion. It was further found that if a lime solution were added immediately prior to chlorination to adjust the pH to a higher value for corrosion correction, a slightly larger and heavier floc with better settling characteristics was formed.

In brief, the succession of effects with lime-chlorine treatment is as follows:

As the water is drawn from the wells the iron present is in the soluble ferrous state, and the water is relatively colorless. The iron is then oxidized by chlorine to the ferric state, in which state it reacts with natural or added alkalinity to form an insoluble flocculent precipitate. In this form it is removed from the water by sedimentation and filtration.

A side effect of this reaction is that the hardness of the water is increased slightly, due to the addition of the calcium ion.

Finally, it was found that the present natural iron content of the well water (8-9 parts per million) is about the minimum amount necessary to form a good floc. If slightly more iron is added to the water a much larger floc is formed. However, the addition of iron salts has the effect of lowering the pH and therefore requiring a greater dosage of lime to attain the optimum pH for corrosion control. With these basic facts gleaned from laboratory jar tests it became a matter of successive trials in varying the chemicals and their dosages to find the minimum amounts necessary to do a satisfactory job in the pilot plant. It was found that by using the amount of iron naturally present in the water and adding 22 parts per million of lime and 9 parts per million of chlorine in that order an effluent could be consistently produced which would have the following characteristics:

(1) Iron content below 0.05 parts per million.
(2) Manganese content of 0.0.
(3) Color below 5 parts per million.
(4) pH at optimum value for corrosion control.
(5) Slight chlorine residual, so as to make post-chlorine unnecessary.

The addition of small amounts of iron salts as a coagulant aid may be necessary in periods of weak flocculation if at some future date cleaning and rehabilitation of the present well field or dilution of the present iron content of the well water by the addition of water from new wells not as rich in iron as the present source should markedly decrease the iron content of the raw water.

Supplementary Studies

One of the most common methods of protecting against the effects of corrosion is to provide a suitable covering on the inside of the pipes. This covering may be something like a tar or cement membrane applied mechanically. However, it is also possible to cause certain protective chemical films to deposit along the inside walls of the pipes and thus minimize corrosion. A layer of rust would be such a film. Calcium carbonate would be another such film.

The degree of corrosiveness of a water depends largely on the interrelationship of three factors: pH value, alkalinity and CO_2 content. It is possible to maintain a relationship between these factors such that a thin protective coating of calcium carbonate will be deposited on the inside of the pipe. The pH at which this will occur is dependent on many variables and hence is different for different waters, but at this optimum pH value, or pH_s as it is designated, an equilibrium is reached whereby this protective coating is deposited on the pipe and will not be dissolved.

To summarize then, with the lime-chlorine treatment indicated the pH of the finished water will be at the optimum value for a slight film of calcium carbonate to deposit on the inside of the pipes of the distribution system. The pH must be maintained at or very near this value. If it falls considerably below it, the film will dissolve. If it rises substantially above it, an excessively thick deposit will form to clog the pipes. However, with laboratory control there should be no serious difficulty in maintaining the optimum pH value and thereby carrying on a continuous and effective corrosion control program.

In all of the foregoing work with both the jar tests and the pilot plant runs an HTH solution was used as the source of the chlorine necessary to oxidize the iron from the ferrous to the ferric state. Inasmuch as there are certain definite advantages to the use of chlorine gas when relatively large amounts of chlorine are constantly required, it was considered worthwhile to investigate the effects of gaseous chlorine as an oxidizing agent. Accordingly series of jar tests were run at the Lawrence Experiment Station using both gaseous chlorine and various other

chlorine-bearing compounds, such as Chlorox, to test their effect against that of the HTH solution.

It was found that color removal and iron removal were in the same range as with the HTH-lime treatment. The other significant factor is that gaseous chlorine depresses the pH considerably. Therefore, to produce an effluent with an optimum pH, it would be necessary to increase the lime dosage to 32 parts per million. The significant factor is that, part for part of chlorine, the gaseous chlorine is as effective as either sodium hypochlorite or calcium hypochlorite. Whether the increased cost of lime would be compensated for by the ease and convenience of using the chlorine gas is mainly an economic problem.

As has been mentioned previously, the Rings Corner Station and well field are located on the banks of the Powow River. It is the understanding of the Department that the town of Amesbury has certain rights to the flow of the river. It was thought that if the final decision was made to continue at the Rings Corner location, rehabilitate the present well field and provide chemical treatment and sand filtration, the river water would be valuable as an emergency source of additional water supply.

Since there was no ready means of providing a continuous flow of river water for use in the pilot plant, continuous flow treatment of this water could not be undertaken. However, jar tests indicate that treatment should present no serious difficulty. A dosage of 25 parts per million of filter alum produced a good floc, which reduced the color to 20 parts per million. The water would then have to be disinfected with chlorine and the pH adjusted for corrosion control. These results indicate only a superficial exploration into the treatment of the surface water with alum, and undoubtedly more work could produce refinements which would result in a much better effluent. As a practical matter what this means is that by providing only an intake structure, sufficient piping and pumping equipment to deliver the river water to the flocculation basin, and an additional machine to feed alum, it would be possible to augment the well water supply with an emergency surface water supply.

In conjunction with the study of the most advantageous way in which to treat Amesbury water, an interesting companion study was initiated to determine the feasibility of so-called "high-

rate filtration." Classically rapid sand filters have been designed to operate in the range of 125 million gallons per acre per day, or about two gallons per square foot per minute. In recent years there has been a tendency to operate filters at higher rates of flow. It is obvious that for any desired quantity of water per given length of time, the faster the rate at which the water can be passed through a sand filter, the smaller in area that filter will have to be. The real and practical benefit of this is the possibility of reducing the initial construction, maintenance and operating costs at higher rates of filtration. However, the filters will clog more rapidly and consequently have to be backwashed more often. The ability to filter at relatively high rates for periods of time without excessive deterioration of quality is very desirable, since it means that it would be possible to design a filter to be operated at conventional rates at the average plant flows anticipated, but at the same time be assured that the same filter would be able to handle easily shock loads such as might occur for limited periods of time in the summer.

The following procedure was adopted for the pilot plant experiment. The chemical dosages, flow rate, flocculation time, sedimentation time and paddle-tip velocities were all maintained constant. In actual practice, however, the time in flocculation and sedimentation tanks would be reduced as the filtration rate was increased. An eight-hour filter run was made at the conventional rate of two gallons per minute per square foot. The volume of water which had passed through the filter was calculated, and then this same amount of water was passed through at rates of 3, 4, 5, 6 and 7 gallons per minute per square foot.

The sand filter was thoroughly backwashed prior to each run. A sample was collected from the sand filter prior to the end of the run, and an effluent sample was also collected from the sedimentation tank. The results showed that at filtering rates up to 6 g.p.m. per square foot a satisfactory effluent could be produced through the rapid sand filter column.

Mr. John R. Baylis, engineer of water purification, city of Chicago, recently reported on a 10-year experiment with high-rate filtration at the South District Filtration Plant. One of the interesting conclusions which he draws from his experiment is that "in filtration plants where a coagulation aid may be used during

periods of weak coagulation, sand filters will produce a satisfactory quality of water operating at a rate of five gallons per minute per square foot of filter surface." The limited experiment conducted on treated Amesbury water seems to substantiate this conclusion.

Summary of Results

1. A research program was carried out to find a suitable treatment for iron and color removal from the Amesbury water supply.

2. Both laboratory jar tests (batch process) and a pilot plant (continuous-flow process) were utilized.

3. With alum as a coagulant, the pilot plant did not accomplish as acceptable a degree of iron removal on the well water as had been indicated by jar tests.

4. With chlorine as an oxidizing agent and lime for pH control, a treated well water was produced after flocculation, sedimentation and rapid sand filtration which consistently had an iron content below 0.05 parts per million, no manganese and a color on the order of 5 parts per million. The proposed treatment with 9 parts per million of chlorine and 22 parts per million of lime also produces a water with a pH quite close to the pH_s indicated for corrosion control. It is indicated that the proposed treatment might be regulated within such limits that no post-chlorination or other further treatment of the filtered water would be required.

5. A simple and relatively easy treatment was devised to treat the water of the adjacent Powow River in the event that this source should be considered as an emergency source of supply. The main problem with the surface water is color, and alum appears to be a better coagulant for the treatment of this source than do the iron salts.

6. In actual plant operation, an increase in the rate of flow through the plant would mean a corresponding decrease in flocculation and sedimentation time. However, the pilot plant studies indicate that if a satisfactory floc were produced at various rates of operation, the rapid sand filter could be operated, at least for limited periods, at rates greatly in excess of the conventional 2 gallons per minute per square foot without a corresponding de-

crease in the quality of effluent. The limiting rates appear to be governed more by hydraulic and head-loss considerations than by any decrease in the efficiency of the filter.

Acknowledgments

Valuable assistance and suggestions were given in the preparation of this paper by the Massachusetts Department of Public Health and by the personnel of the Lawrence Experiment Station.

The assistance of the Department of Public Works of Amesbury and the various officials of the town of Amesbury in providing the space and facilities for this experiment is also gratefully acknowledged.

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PROCEEDINGS

FEBRUARY 1961 MEETING

STATLER-HILTON HOTEL, BOSTON, MASS.

THURSDAY, FEBRUARY 16, 1961

President Kenneth W. Robie in the Chair.

Secretary Joseph C. Knox announced the election of the following new members:

John A. Cronin, Sales Engineer, Worthington Corporation, Boston, Mass.; Nathan S. Ellis, III, Superintendent, Water Works, New Bedford, Mass.; George W. Low, Director, Water Department, Warwick, Rhode Island.; Henry F. Stearns, District Sales Manager, Chicago Bridge and Iron Company, Boston, Mass.; Raymond J. Donlan, Chief of Laboratory, Lawrence Experiment Station, Massachusetts Department of Public Health, Lawrence, Mass.

PRESIDENT ROBIE. Before proceeding with the afternoon program I have a sad duty to perform. We have recently received announcement of the deaths of the following members of the Association. Will you please rise in silent tribute while I read their names? (*The members stand.*)

Edwin L. Jette, Mystic, Conn.
Maurice A. Libby, Bath, Maine.
Frank X. Pooley, Woonsocket, R.I.
John M. Reilly, Fairhaven, Mass.
Edwin F. Rothman, Waban, Mass.

May they rest in peace!

A paper on "New Water–Filtration Plant, Kittery Water District, Kittery, Maine," was read by Paul F. Howard, Treasurer, Whitman and Howard, Boston, Mass.

A paper, entitled "Two-Tank Failure, New London, Connecticut," was read by Clifford S. Mansfield, Senior Engineer, Fay, Spofford and Thorndike, Inc., Boston, Mass.

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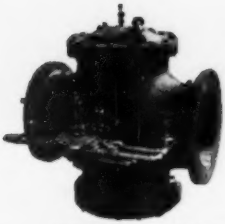

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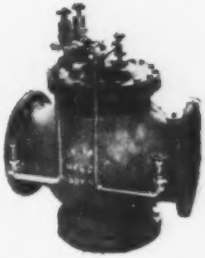

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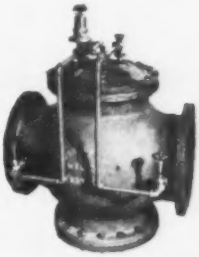

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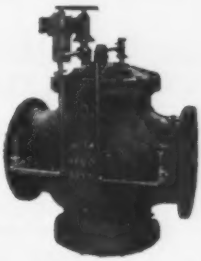

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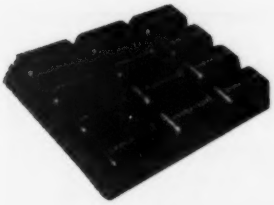

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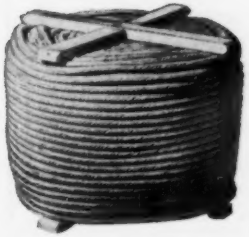

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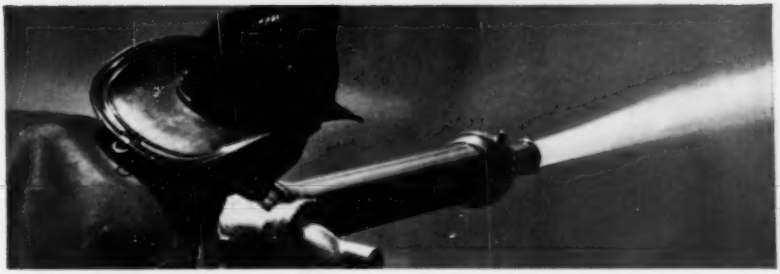

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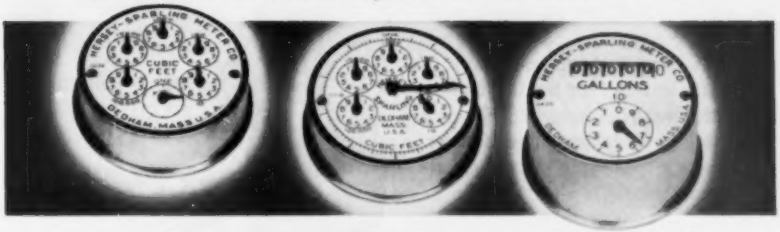

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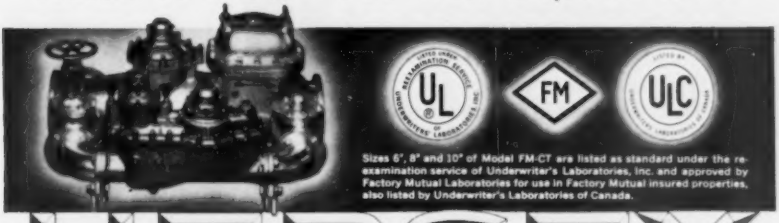
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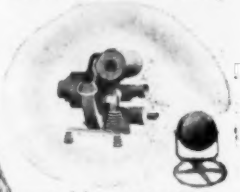

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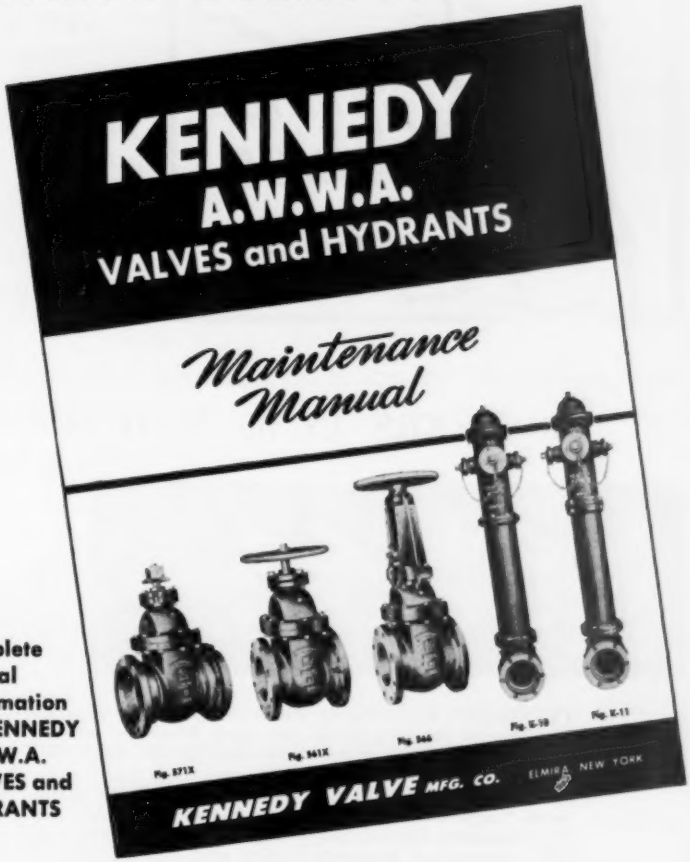

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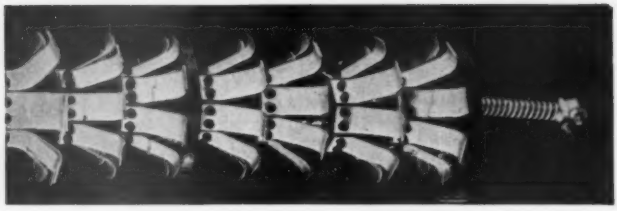

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ERRATA

This standard should have been included in Vol. 75, No. 2, June, 1961, as listed in the table of contents for that issue.

AWWA C202–60T

American Water Works Association

TENTATIVE
AWWA STANDARD
for
MILL-TYPE STEEL WATER PIPE

This "Standard for Mill-Type Steel Water Pipe" is based upon the best known experience and is intended for use under normal conditions. It is not designed for unqualified use under all conditions, and the advisability of its use for any installation must be subjected to review by the engineer responsible.

First Edition approved Apr. 25, 1940; Second Edition approved as "Tentative" May 15, 1960.

AMERICAN WATER WORKS ASSOCIATION
Incorporated
2 Park Avenue, New York 16, N.Y.

Prepared by

Water Works Practice Committee 8310 D

Acknowledgment is made and appreciation is expressed to the Subcommittee on Pipe of the Steel Water Pipe Manufacturers Technical Advisory Committee for its assistance in the preparation of this standard. The officers of this committee are R. C. Beam, chairman; Walter H. Cates, secretary.

Latest Revisions to C202

This Second Edition of AWWA Standard C202 was approved as "Tentative" on May 15, 1960. The principal change involved is that this edition covers mill-type pipe in all sizes, whereas the First Edition covered both fabricated and mill-type pipe in sizes up to, but not including, 30 in.

Designation. As a result of the revision, the former designation, "C202–59," has been changed to "C202–60T."

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AWWA C202–60T

Tentative AWWA Standard for

Mill-Type Steel Water Pipe

Section 1—General

Sec. 1.1—Scope

This standard covers mill-type steel pipe intended for the conveyance of water. It covers pipe in all sizes; in single or double random lengths or specified laying lengths; in straight sections or other special sections required for closures, curves, or changes in alignment or grade to meet special conditions; and with ends prepared for the type of joint specified. For the purpose of this standard, mill-type pipe is defined as furnace-welded, electrically welded, or seamless steel pipe of any size produced to meet finished-pipe specifications. The types of pipe covered by this standard shall be limited by the following provisions:

1.1.1. *Furnace-welded pipe.* Furnace-welded pipe shall be continuous butt welded or furnace butt welded.

1.1.2. *Electrically welded pipe.* Electrically welded pipe shall be of Grade A, B, or X42,* as specified by the purchaser, and shall be induction butt welded; spiral- or straight-seam resistance butt welded; or spiral- or straight-seam fusion butt welded. Fusion-butt-welded pipe shall be manufactured by automatic submerged-arc or automatic shielded-arc welding.

1.1.3. *Seamless pipe.* Seamless pipe shall be of Grade A, B, or X42, as specified by the purchaser.

Sec. 1.2—Definitions

Under this standard, the following definitions shall apply:

1.2.1. *Purchaser:* The person, firm, corporation, or governmental subdivision entering into a contract or agreement for the purchase of any materials or work to be performed under this standard.

1.2.2. *Contractor:* The person, firm, or corporation executing the contract or agreement with the purchaser to furnish any material or perform any work.

1.2.3. *Inspector:* The duly authorized representative of the purchaser qualified by training and experience in the manufacture of steel pipe of the character covered by this standard.

1.2.4. *Bevel:* An angle applied on the end of a pipe and measured from a line perpendicular to the axis.

1.2.5. *Butt weld:* A weld whose throat lies in a plane disposed approximately 90 deg with respect to the surfaces of at least one of the parts joined.

* Grades A and B under this standard are similar to grades A and B for pipe under American Petroleum Institute API 5L (Specifications for Line Pipe). Grade X42 is similar to Grade X42 for pipe under API 5LX (Specifications for High-Test Line Pipe). The purchaser need not make reference to the API specifications in using this standard, however.

The size of a butt weld is expressed in terms of its net or unreinforced throat dimension in inches. A double-welded butt joint is one in which the filler metal is added to both sides. A single-welded butt joint is one in which the filler metal is added to one side only.

1.2.6. *Fillet weld:* A weld of approximately triangular cross section whose throat lies in a plane disposed approximately 45 deg with respect to the surfaces of the parts joined. The size of the fillet weld is expressed in terms of the width, in inches, of one of its adjacent fused legs, the shorter if unequal.

1.2.7. *Flame cutting:* The process of severing metal by means of a gas flame.

1.2.8. *Furnace-welded pipe:* Either bell-welded or continuously welded pipe.

1.2.9. *Bell-welded pipe:* Pipe produced in individual lengths from cut-length skelp, having its longitudinal butt joint forge welded by the mechanical pressure developed in drawing the furnace-heated skelp through a cone-shaped die (commonly known as a "welding bell") which serves as a combined forming and welding die.

1.2.10. *Continuous-welded pipe:* Pipe produced in continuous lengths from coiled skelp and subsequently cut into individual lengths, having its longitudinal butt joint forge welded by the mechanical pressure developed in rolling the hot-formed skelp through a set of round-pass welding rolls.

1.2.11. *Fusion welding:* The process of welding metals in the molten or molten and vaporous state, without the application of mechanical pressure or blows.

1.2.12. *Girth weld:* A circumferential welded seam lying in one plane, used to join sections into lengths of straight pipe or to join pieces of mitered pipe to form fabricated special sections and fittings.

1.2.13. *Grade or class of material:* The designation of material as to chemical analysis or physical properties.

1.2.14. *Ladle analysis:* The chemical analysis taken at the time the steel is cast into ingots.

1.2.15. *Manufacturing process:* The designation of pipe in accordance with the method of manufacture (see Sec. 1.1).

1.2.16. *Mill-type pipe:* Seamless, furnace-welded, electrically welded, or furnace-butt-welded steel pipe of any size produced to meet finished-pipe specifications.

1.2.17. *Nominal outside diameter:* The commercial name or given dimension for pipe in sizes up to 12 in., as distinguished from the actual or measured dimension.

1.2.18. *Nominal size:* The commercial name or given dimension for pipe in sizes up to 12 in., as distinguished from the actual or measured dimension.

1.2.19. *Nominal wall thickness:* The named or given thickness as distinguished from the actual or measured thickness.

1.2.20. *Nominal weight per foot* (for uncoated and unlined pipe): The theoretical weight per foot, as shown in published tables, as distinguished from the actual or measured weight per foot of the finished pipe.

1.2.21. *Plain-end pipe:* Pipe cut off to random or exact lengths, but not threaded. It is not beveled unless so specified.

1.2.22. *Resistance-butt-welded pipe:* Pipe having a longitudinal or spiral butt joint in which coalescence is produced by the heat obtained from re-

sistance of the pipe to the flow of electric current in a circuit of which the pipe is a part, and by the application of pressure.

1.2.23. *Root:* The zone at the bottom of the cross-sectional space provided to contain the deposited filler metal.

1.2.24. *Seamless pipe:* Pipe without welds made from solid ingots, blooms, billets, or round bars which have been hot pierced and then brought to the desired size by hot rolling, hot drawing, or a combination of both.

1.2.25. *Specified lengths:* Sections of finished pipe whose length dimensions do not vary from a fixed figure specified by the purchaser by more than the tolerance set forth in this standard.

1.2.26. *Spiral-seam fusion-welded pipe:* Pipe in which the line of the fusion seam forms a helix on the barrel of the pipe.

1.2.27. *Straight-seam fusion-welded pipe:* Pipe in which the line of the fusion seam parallels the axis of the pipe.

1.2.28. *Throat:* The thickness of deposited weld metal, not including reinforcing, along a straight line passing through the root.

1.2.29. *Handling-tight coupling:* A threaded coupling sufficiently tight that a wrench is necessary to loosen it.

1.2.30. *Power-tight coupling:* A threaded coupling sufficiently tight that it cannot be loosened by the application of a manual wrench alone.

Sec. 1.3—Supplementary Details to Be Specified by Purchaser

When purchasing pipe under this standard, the purchaser shall provide specific supplementary information in his specifications regarding the following details:

1.3.1. Outside diameter.

1.3.2. Wall thickness.

1.3.3. Grade or class designation.

1.3.4. Minimum mill hydrostatic test pressure.

1.3.5. Type of field joints (description or drawings).

1.3.6. Lengths—that is, whether single random (average length 17½ ft), double random (average length 35 ft), or specified cut length (see Sec. 7.4.1 for percentage of minimum and maximum lengths).

1.3.7. The maximum number of longitudinal and girth seams permitted in each length.

1.3.8. All special sections and special fittings, indicating, for each component part, the dimensions and type of field joint together with length tolerances.

1.3.9. Whether a certified statement from the contractor that the required inspection and tests have been made is desired.

1.3.10. Any exceptions to variations from this standard for special requirements for further processing.

Sec. 1.4—Inspection

1.4.1. All work done and material furnished under this standard may be inspected by the purchaser, but such inspection shall not relieve the manufacturer of his responsibility to furnish material and perform work in accordance with this standard. If the inspector desires to inspect the pipe or witness the tests, reasonable notice shall be given of the time at which the inspection is to be made. When requested by the purchaser, a certified statement from the manufacturer that the required inspection and tests have been made shall be furnished.

1.4.2. At all times while work on the contract is being performed the inspector shall have free entry to all parts of the manufacturer's works which concern the manufacture of the pipe ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the pipe is being manufactured in accordance with this standard. All inspections shall be made at the place of manufacture prior to shipment and shall be so conducted as not to interfere unnecessarily with the operation of the works.

1.4.3. The inspector may reject any or all pipe sections or special sections that do not conform to the prescribed test results, conditions of pipe, and tolerances set forth in this standard, the approved drawings, and in the purchaser's supplementary specifications.

Sec. 1.5—Workmanship

1.5.1. *Defects.* The finished pipe shall be free from injurious defects. Defects in seamless pipe or in the parent metal of welded pipe shall be considered injurious when the depth of defect is greater than 12.5 per cent of the tabulated wall thickness. All cracks, sweats, and leaks in welds shall be considered injurious. All end welding of longitudinal seams of fusion-welded pipe, if not done by automatic submerged-arc or automatic shielded-arc welding, shall be done by a procedure and a welder qualified in accordance with Sec. 6.

1.5.2. *Repair of defects.* The repair of injurious defects shall be permitted at the discretion of the manufacturer, except that the repair of defects in seamless pipe or in the parent metal of welded pipe shall not be permitted if the depth of defect exceeds one-third of the tabulated wall thickness of the pipe and the length of that portion of the defect in which the depth exceeds 12.5 per cent is greater than 25 per cent of the tabulated outside diameter of the pipe, or if more than one repair is required in any length equivalent to ten times the tabulated outside diameter of the pipe. Repairs shall conform to the following requirements:

a. The defect shall be completely removed and the cavity thoroughly cleaned.

b. The repair weld shall be made by either automatic or manual welding, by a procedure and a welder qualified in accordance with Sec. 6.

c. Each length of repaired pipe shall be tested hydrostatically in accordance with Sec. 4.1.

Section 2—Chemical Properties and Tests

Sec. 2.1—Chemical Properties

The steel furnished for pipe under this standard shall be of good welding quality and shall conform to the chemical requirements shown in Table 1 for the grade of pipe ordered. Steel may be made by any of the following processes, in accordance with the method of pipe manufacture: open hearth, electric furnace, basic oxygen, killed deoxidized acid, or basic bessemer.

Sec. 2.2—Tests

2.2.1. *Ladle analysis.* When requested by the purchaser, the manufacturer shall furnish a report giving the ladle analysis of each heat of open-hearth, electric-furnace, or basic-oxygen

steel and such analyses as the manufacturer may customarily make of bessemer steel used in the manufacture of pipe conforming to this standard. The analyses so determined shall conform to the requirements specified in Table 1.

2.2.2. *Check analysis.* When so specified on the purchase order, the manufacturer shall furnish a report of check analysis on finished pipe $2\frac{3}{8}$ in. and larger. The number of samples for check analysis shall be one from each of two lengths of pipe from each lot of 400 lengths or fewer of each size $2\frac{3}{8}$ in. through $5\frac{9}{16}$ in., one from each of two lengths from each lot of 200 lengths or fewer of each size $6\frac{5}{8}$ in. through 20 in., and one from each of two lengths from each lot of 100 lengths or fewer of each size 22 in. and larger. For multiple-length pipe, a length shall be considered as all of the sections cut from a particular multiple length. The samples shall be taken as follows:

TABLE 1

Chemical Requirements for Ladle Analysis

Type of Steel	Maximum Content—*per cent*		
	Manganese	Phosphorus	Sulfur
Furnace butt welded	0.65	0.11	0.06
Grade A	1.25	0.04	0.05
Grade B	1.25	0.11	0.05
Grade X42	1.25	0.10	0.05

a. Seamless pipe. At the option of the manufacturer, cuttings or drillings for check analysis shall be taken either from tensile test specimens or from the pipe at several points around the finished pipe. If drillings are used, the minimum drill size shall be $\frac{1}{2}$ in. and drillings shall be taken by drilling all the way through the pipe wall.

b. Welded pipe. At the option of the manufacturer, cuttings or drillings for check analysis shall be taken from the finished pipe, plate, skelp, tensile-test specimens, or flattening-test specimens. The location of the samples shall be approximately 90 deg from the weld. Samples shall be taken in such a manner as to represent the total wall thickness. The minimum drill size shall be $\frac{1}{2}$ in. The composition so determined shall conform to the ladle analysis limits, and permissible variations shall not exceed the following amounts: manganese, +0.05 per cent; phosphorus, +0.01 per cent; sulfur, +0.01 per cent.

2.2.3. *Recheck analysis.* If the check analysis of both lengths of pipe representing the lot fails to conform to the specified requirements, at the manufacturer's option, either the lot shall stand rejected or all the remaining lengths in the lot shall be tested individually for conformance to the specified requirements. If only one of the two samples fails, at the manufacturer's option, either the lot shall stand rejected or two recheck analyses shall be made on two additional lengths from the same lot. If both recheck analyses conform to the requirements, the lot shall be accepted except for the length represented by the initial analysis which failed. If one or both of the recheck analyses fail, at the manufacturer's option, the entire lot shall be rejected or each of the remaining lengths shall be tested individually. In the individual testing of the remaining lengths in any lot, analysis for only the disqualifying element or elements need be determined. Samples for recheck analysis shall be taken in the same manner as specified for check analysis samples.

Section 3—Mechanical Properties and Tests

Sec. 3.1—Mechanical Properties

Pipe furnished under this standard shall conform to the tensile properties specified in Table 2 for the particular grade ordered. The yield strength shall be the tensile stress required to produce a total elongation, under load, of 0.5 per cent of the gage length, as determined by an extensometer or by multiplying dividers. Minimum elongation requirements for seamless and electrically welded pipe shall be those in Table 3 for the particular grade ordered. If the tabulated wall thickness of seamless or electrically welded pipe is other than those listed in Table 3 or less than 0.312 in., the minimum elongation requirement shall be determined by one of the following formulas:

Grade	Formula
A	$E = 56t + 17.50$
B	$E = 48t + 15.00$
X42	$E = 40t + 12.50$

in which E is the minimum elongation in 2 in. (in per cent) and t is the tabulated wall thickness (in inches). Minimum elongation and gage length requirements for furnace-butt-welded pipe 1.050 in OD and smaller shall be those set forth in Table 4.

TABLE 2

Minimum Tensile Requirements for Mill-Type Steel Water Pipe

Type of Steel	Tensile Strength *psi*	Yield Point *psi*
Furnace butt welded	45,000	25,000
A	48,000	30,000
B	60,000	35,000
X42	60,000	42,000

TABLE 3

Minimum Elongation Requirements for Seamless and Electrically Welded Mill-Type Steel Water Pipe

Tabulated Wall Thickness *in.*	Grade A	Grade B	Grade X42
	Elongation in 2 in.—*per cent*		
0.312 and larger	35.00	30.00	25.00
0.281	33.25	28.50	23.75
0.250	31.50	27.00	22.50
0.219	29.75	25.50	21.25
0.188	28.00	24.00	20.00
0.156	26.25	22.50	
0.124	24.50	21.00	
0.094	22.75	19.50	
0.062	21.00	18.00	

Sec. 3.2—Tensile Tests

For seamless and furnace-butt-welded pipe in all sizes and for electric-welded pipe 6⅝ in. and smaller, the tensile properties shall be determined by tests on longitudinal specimens conforming to the requirements of Sec. 3.2.1. For electric-welded pipe 8⅝ in. and larger, the tensile-test specimens may be taken transversely; specimens shall conform to the requirements of Sec. 3.2.2. Tensile tests on all longitudinal specimens and on all transverse body test specimens shall include yield strength, tensile strength, and elongation determinations. At the option of the manufacturer, transverse yield strength may be determined by the ring expansion method. Transverse weld test specimens need be tested for tensile strength only. All tensile tests shall be made with the specimens at room temperature.

3.2.1. *Longitudinal tensile-test specimens.* Longitudinal tensile-test speci-

mens shall be either full-section specimens or strip specimens, at the option of the manufacturer. Strip specimens from seamless pipe may be taken from any location, at the option of the manufacturer. Strip specimens shall be taken approximately 90 deg from the weld or, at the option of the manufacturer, from the skelp, parallel to the direction of rolling and approximately midway between the edge and the center. All longitudinal strip specimens shall be approximately 1½ in. wide in the gage length if suitable curved-face testing grips are at hand; otherwise, they shall be approximately ¾ in. wide for pipe 3½ in. and smaller, approximately 1 in. wide for pipe 4 in. through 6⅝ in., and approximately 1½ in. wide for pipe 8⅝ in. and larger. Longitudinal test specimens shall represent the full wall thickness of the pipe from which the specimens were cut and shall be tested without flattening.

3.2.2. *Transverse tensile-test specimens.* Transverse body test specimens from electric-welded pipe shall be taken opposite the weld; transverse weld test specimens shall be taken with the weld at the center of the specimen. All transverse test specimens shall be approximately 1½ in. wide in the gage length, and shall represent the full wall thickness of the pipe from which the specimens were cut.

3.2.3. *Number of tensile tests required.* One tensile test shall be made on one length of pipe from each lot of 400 lengths or fewer of each size 6 in. and smaller, from each lot of 200 lengths or fewer of each size 6⅝ in. through 20 in. and from each lot of 100 lengths or fewer of each size 22 in. and larger. For multiple-length pipe, a length shall be considered as all of the sections cut from a particular multiple length. For electric-welded pipe, one transverse tensile test shall be made of the weld on a length of pipe from each lot of 200 lengths or fewer of each size 8⅝ in. through 12¾ in. and from each lot of 100 lengths or fewer of each size 14 in. and larger.

3.2.4. *Retest.* If the tensile-test specimen representing a lot of pipe fails to conform to the specified requirements, the manufacturer may elect to make restests on two additional lengths from the same lot. If both of the retest specimens conform to the requirements, all the lengths in the lot shall be accepted except the length from which the initial specimen was taken. If one or both of the retest specimens fail to conform to the specified requirements, the manufacturer may elect to test individually the remaining lengths in the lot, in which case, determinations are required only for the particular requirements with which the specimens failed to comply in the preceding tests. Specimens for retests shall be taken in the same manner as specified in Sec. 3.2.1 and Sec. 3.2.2. If any tensile-test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted. When the elon-

TABLE 4

Minium Elongation and Gage Length Requirements for Furnace-Butt-Welded Pipe 1.050 in. OD and Smaller

Outside Diameter *in.*	Nominal Size *in.*	Gage Length *in.*	Elongation in 8 in. *per cent*
1.050	¾	6	18
0.840	½	6	18
0.675	⅜	4	18
0.540	¼	4	18
0.405	⅛	2	18

gation of any tensile-test specimen is less than that specified, if any part of the fracture is outside of the middle third of the gage length as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

Sec. 3.3—Flattening Tests

3.3.1. *Nonexpanded electric-welded* pipe. For nonexpanded electric-welded pipe (except automatic-fusion-welded pipe) produced in single lengths, the crop ends cut from each length shall be flattened between parallel plates, with the weld at the point of maximum bending, until opposite

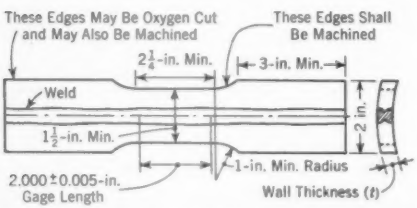

Fig. 1. Tensile-Elongation Test Specimen

The weld reinforcement shall be removed from both faces of the specimen.

walls of the pipe meet. No opening in the weld shall appear until the distance between the plates is less than two-thirds of the original outside diameter of the pipe, and no cracks or breaks in the metal shall occur elsewhere than in the weld until the distance between the plates is less than one-third of the original outside diameter of the pipe. Also, evidence of laminations or burned metal shall not develop during the entire flattening operation. If any crop end fails to conform to these requirements, additional tests shall be made on specimens cut from the same end of the same length of pipe until the requirements are met, except that the finished pipe shall not be shorter than 80 per cent of its length after the initial cropping. Precautions shall be taken that crop ends can be identified with respect to the length of pipe from which they were cut.

3.3.2. *Nonexpanded resistance-welded pipe.* For nonexpanded resistance-welded pipe produced in multiple lengths and subsequently cut into single lengths, a flattening test shall be made as described in Sec. 3.3.1 above on test specimens cut from each end of each coil. If one or both of the specimens fail to conform to the requirements, the manufacturer may elect to make retests on specimens cut from each end of each individual length.

3.3.3. *Cold-expanded electric-welded pipe.* For cold-expanded electric-welded pipe (except automatic fusion-welded pipe), a flattening test shall be made as described in Sec. 3.3.1 above on a ring 4 in. or wider cut from one end of a length of pipe from each lot of 100 lengths or fewer of each size. If the specimen fails to conform to the requirements, the manufacturer may elect to make retests on specimens cut from one end of two additional lengths from the same lot. If both retest specimens conform to the specified requirements, all the lengths in the lot shall be accepted except the length from which the initial specimen was taken. If one or both of the retest specimens fail to conform to the specified requirements, the manufacturer may elect to repeat the test on specimens cut from one end of the individual lengths remaining in the lot.

3.3.4. *Butt-welded pipe 2⅞ in. and larger.* For butt-welded pipe 2⅞ in. and larger, one section of pipe approxi-

mately 6 in. long, cut from a length from each lot of 400 lengths or fewer, of each size, shall be flattened between parallel plates with the weld located approximately 45 deg from the point of maximum bending. No cracks shall occur in any portion of the pipe, and no opening shall occur in the weld until the distance between the plates is less than 60 per cent of the original outside diameter of the pipe. If the specimen fails to conform to these requirements, the manufacturer may elect to make retests on specimens cut from two additional lengths from the same lot. If all retest specimens conform to the specified requirements, all the lengths in the lot shall be accepted except the length from which the initial specimen was taken. If one or more of the retest specimens fail to conform to the specified requirements, the manufacturer may elect to repeat the test on specimens cut from the individual lengths remaining in the lot.

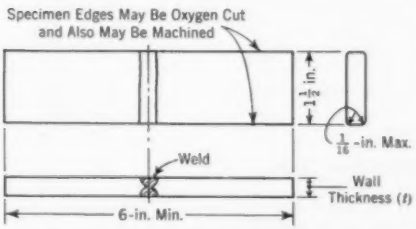

Fig. 2. Guided-Bend Test Specimen

The weld reinforcement shall be removed from both faces of the specimen.

Sec. 3.4—Bend Tests for Butt-Welded Pipe

For butt-welded pipe $2\frac{3}{8}$ in. and smaller, one full-section specimen of appropriate length, cut from a length of pipe from each lot of 400 lengths or fewer of each size, shall be bent cold through 90 deg around a mandrel having a diameter not greater than twelve times the outside diameter of the pipe being tested, with the weld located approximately 45 deg from the point of contact of the specimen with the mandrel. No cracks shall occur in any portion of the pipe, and no opening shall occur in the weld. If the specimen fails to conform to these requirements, the manufacturer may elect to make retests on specimens cut from two additional lengths from the same lot. If all retest specimens conform to the specified requirements, all the lengths in the lot shall be accepted except the length from which the initial specimen was taken. If one or more of the retest specimens fail to conform to the specified requirements, the manufacturer may elect to repeat the test on specimens cut from the individual lengths remaining in the lot.

Sec. 3.5—Fusion Weld Tests

For fusion-welded pipe, the weld shall be tested by either of the tests described below, at the option of the manufacturer. The required specimens shall be cut from a length of pipe from each lot of 100 lengths or less of each size. The specimens shall not contain any repair welding made by the manual metallic-arc procedure.

3.5.1. *Tensile-elongation test.* One specimen conforming to Fig. 1 shall be tested in tension, and shall conform to the elongation requirements specified in Table 2.

3.5.2. *Guided-bend test.* One face bend specimen conforming to Fig. 2 shall be bent approximately 180 deg in a jig substantially in accordance with Fig. 3. The specimen shall not fracture completely, and no cracks ex-

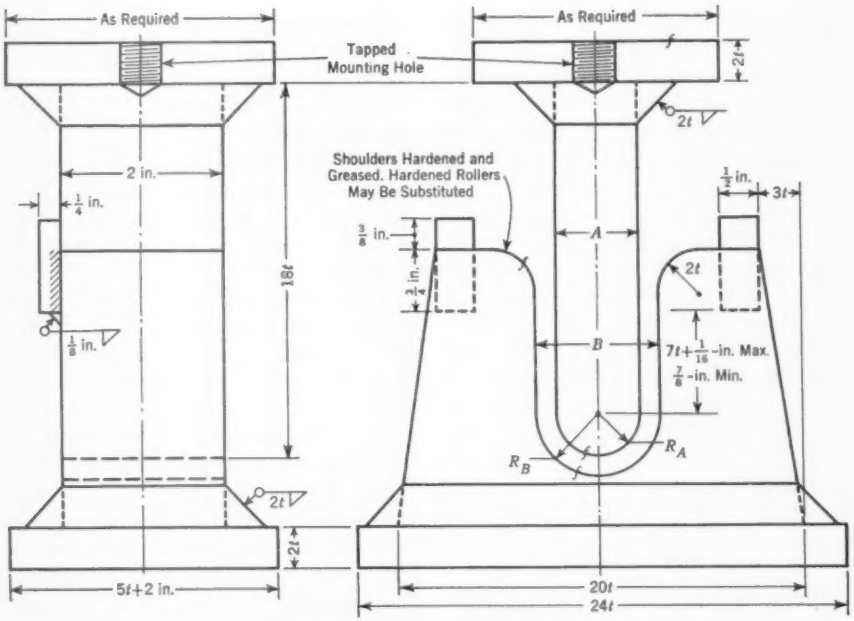

Fig. 3. Jig for Guided-Bend Test

The symbol "f" indicates a light finish cut; t *is the tabulated wall thickness of the pipe. For pipe of Grade A or B, the dimensions* A *and* B *shall be* 4t *and* 6t + $\frac{1}{8}$ *in., respectively; for pipe of Grade X42, these dimensions shall be* 6t *and* 8t + $\frac{1}{8}$ *in., respectively* ($R_A = \frac{1}{2}$ A *and* $R_B = \frac{1}{2}$ B).

ceeding $\frac{1}{8}$ in. in any direction shall be present in the weld metal or between the weld metal and pipe metal. Cracks which originate at the edges of the specimen and which are less than $\frac{1}{4}$ in. long shall not be cause for rejection.

3.5.3. *Retests.* If the tensile-elongation specimen or the guided-bend specimen fails to conform to the specified requirements, the manufacturer may elect to repeat the test on specimens cut from two additional lengths of pipe from the same lot. If such specimens conform to the specified requirements, all the lengths in the lot shall be accepted, except the length initially selected for the test. If any of the retest specimens fails to pass the specified requirements, the manufacturer may elect to test specimens cut from the individual lengths remaining in the lot. Specimens for retests shall be taken in the same manner as specified in Sec. 3.5.1 and Sec. 3.5.2.

TABLE 5

Dimensions, Weights, and Test Pressures for Mill-Type Steel Water Pipe

Nominal Size *in.*	Outside Diam. *in.*	Inside Diam. *in.*	Weight per Linear Foot* *lb*	Wall Thickness *in.*		Butt Welded	Grade A	Grade B
				Decimal	Fraction	Test Pressure—*psi*		
⅛	0.405	0.269	0.24†	0.068	1/16	700	700	700
¼	0.540	0.364	0.42†	0.088		700	700	700
⅜	0.675	0.493	0.57†	0.091	3/32	700	700	700
½	0.840	0.622	0.85†	0.109	7/64	700	700	700
¾	1.050	0.824	1.13†	0.113		700	700	700
1	1.315	1.049	1.68†	0.133		700	700	700
1¼	1.660	1.380	2.27†	0.140	9/64	800	1,000	1,100
1½	1.900	1.610	2.72†	0.145		800	1,000	1,100
2	2.375	2.067	3.65†	0.154	5/32	800	1,000	1,100
2½	2.875	2.469	5.79†	0.203	13/64	800	1,000	1,100
3	3.500	3.068	7.58†	0.216	7/32	800	1,000	1,100
3	3.500	3.250	4.51	0.125	⅛		1,300	1,500
		3.188	5.58	0.156	5/32		1,600	1,900
		3.124	6.63	0.188	3/16		1,900	2,200
		3.068	7.58	0.216	7/32		2,200	2,500
		3.000	8.68	0.250	¼		2,500	2,500
		2.938	9.67	0.281	9/32		2,500	2,500
3½	4.000	3.750	5.17	0.125	⅛		1,100	1,300
		3.688	6.41	0.156	5/32		1,400	1,600
		3.624	7.63	0.188	3/16		1,700	2,000
		3.548	9.11†	0.226		1,200	2,000	2,400
		3.500	10.01	0.250	¼		2,200	2,500
		3.438	11.17	0.281	9/32		2,500	2,500
4	4.500	4.250	5.84	0.125	⅛		1,000	1,200
		4.188	7.25	0.156	5/32		1,200	1,500
		4.124	8.64	0.188	3/16		1,500	1,800
		4.062	10.00	0.219	7/32		1,700	2,000
		4.026	10.79†	0.237	15/64	1,200	1,900	2,200
		4.000	11.35	0.250	¼		2,000	2,300
		3.938	12.67	0.281	9/32		2,200	2,500
		3.876	13.98	0.312	5/16		2,500	2,500
5	5.563	5.251	9.02	0.156	5/32		1,000	1,200
		5.187	10.76	0.188	3/16		1,200	1,400
		5.125	12.49	0.219	7/32		1,400	1,700
		5.047	14.62†	0.258			1,700	1,900
		5.001	15.87	0.281	9/32		1,800	2,100
		4.939	17.52	0.312	5/16		2,000	2,400
		4.875	19.16	0.344	11/32		2,200	2,500

* Plain end.
† Standard weight.

TABLE 5—*Physical Data for Mill-Type Pipe (contd.)*

Nominal Size *in.*	Outside Diam. *in.*	Inside Diam. *in.*	Weight per Linear Foot* *lb*	Wall Thickness *in.*		Grade A	Grade B
				Decimal	Fractional	Test Pressure—*psi*	
6	6.625	6.249	12.89	0.188	3/16	1,000	1,200
		6.187	14.97	0.219	7/32	1,200	1,400
		6.125	17.02	0.250	1/4	1,400	1,600
		6.065	18.97†	0.280	9/32	1,500	1,800
		6.001	21.07	0.312	5/16	1,700	2,000
		5.937	23.06	0.344	11/32	1,900	2,200
		5.875	25.03	0.375	3/8	2,000	2,400
8	8.625	8.249	16.90	0.188	3/16	800	900
		8.187	19.64	0.219	7/32	900	1,100
		8.125	22.36	0.250	1/4	1,000	1,200
		8.071	24.70†	0.277		1,200	1,300
		8.001	27.74	0.312	5/16	1,300	1,500
		7.981	28.55†	0.322	21/64	1,300	1,600
		7.937	30.40	0.344	11/32	1,400	1,700
		7.875	33.04	0.375	3/8	1,600	1,800
		7.749	38.26	0.438	7/16	1,800	2,100
10	10.750	10.374	21.15	0.188	3/16	650	750
		10.312	24.60	0.219	7/32	750	850
		10.250	28.04	0.250	1/4	850	1,000
		10.192	31.20†	0.279	9/32	1,000	1,200
		10.136	34.24†	0.307		1,000	1,200
		10.062	38.20	0.344	11/32	1,100	1,300
		10.020	40.48†	0.365		1,200	1,400
		9.874	48.19	0.438	7/16	1,500	1,700
12	12.750	12.312	29.28	0.219	7/32	600	700
		12.250	33.38	0.250	1/4	700	800
		12.188	37.45	0.281	9/32	800	950
		12.126	41.51	0.312	5/16	900	1,000
		12.090	43.77†	0.330		1,000	1,200
		12.062	45.55	0.344	11/32	1,000	1,200
		12.000	49.56†	0.375	3/8	1,100	1,300
		11.938	53.56	0.406	13/32	1,100	1,300
		11.874	57.53	0.438	7/16	1,200	1,400
14	14.000	13.500	36.71	0.250	1/4	650	750
		13.438	41.21	0.281	9/32	700	850
		13.376	45.68	0.312	5/16	800	950
		13.312	50.14	0.344	11/32	900	1,000
		13.250	54.57†	0.375	3/8	950	1,100
		13.124	63.37	0.438	7/16	1,100	1,300
		13.000	72.09	0.500	1/2	1,300	1,500
16	16.000	15.500	42.05	0.250	1/4	550	650
		15.438	47.22	0.281	9/32	650	750
		15.376	52.36	0.312	5/16	700	800
		15.312	57.48	0.344	11/32	750	900
		15.250	62.58†	0.375	3/8	850	1,000
		15.124	72.72	0.438	7/16	1,000	1,100
		15.000	82.77	0.500	1/2	1,100	1,300

* Plain end.
† Standard weight.

TABLE 5—*Physical Data for Mill-Type Pipe (contd.)*

Nominal Size *in.*	Outside Diam. *in.*	Inside Diam. *in.*	Weight per Linear Foot* *lb*	Wall Thickness *in.*		Grade A	Grade B	Grade X42
				Decimal	Fractional	Test Pressure—*psi*		
18	18.000	17.500	47.39	0.250	1/4	500	600	
		17.438	53.22	0.281	9/32	550	650	
		17.376	59.03	0.312	5/16	600	750	
		17.312	64.82	0.344	11/32	700	800	
		17.250	70.59†	0.375	3/8	750	900	
		17.124	82.06	0.438	7/16	900	1,000	
		17.000	93.45	0.500	1/2	1,000	1,200	
20	20.000	19.500	52.73	0.250	1/4	450	500	
		19.438	59.23	0.281	9/32	500	600	
		19.376	65.71	0.312	5/16	550	650	
		19.312	72.16	0.344	11/32	600	700	
		19.250	78.60†	0.375	3/8	700	800	
		19.124	91.41	0.438	7/16	800	900	
		19.000	104.13	0.500	1/2	900	1,000	
22	22.000	21.376	72.38	0.312	5/16	500	600	
		21.312	79.51	0.344	11/32	550	650	
		21.250	86.61	0.375	3/8	600	700	
		21.124	100.75	0.438	7/16	700	850	
		21.000	114.81	0.500	1/2	800	950	
24	24.000	23.500	63.41	0.250	1/4	400	450	790
		23.438	71.25	0.281	9/32	400	500	890
		23.376	79.06	0.312	5/16	450	550	990
		23.312	86.85	0.344	11/32	500	600	1,090
		23.250	94.62	0.375	3/8	550	650	1,190
		23.188	102.37	0.406	13/32	600	700	1,280
		23.124	110.10	0.438	7/16	650	750	1,380
		23.000	125.49	0.500	1/2	750	850	1,580
26	26.000	25.500	68.75	0.250	1/4			730
		25.438	77.25	0.281	9/32			820
		25.376	85.73	0.312	5/16			910
		25.312	94.19	0.344	11/32			1,010
		25.250	102.63	0.375	3/8			1,100
		25.188	111.05	0.406	13/32			1,190
		25.124	119.44	0.438	7/16			1,280
		25.062	127.82	0.469	15/32			1,370
		25.000	136.17	0.500	1/2			1,460
28	28.000	27.500	74.09	0.250	1/4			680
		27.438	83.26	0.281	9/32			760
		27.376	92.41	0.312	5/16			850
		27.312	101.53	0.344	11/32			930
		27.250	110.64	0.375	3/8			1,020
		27.188	119.72	0.406	13/32			1,100
		27.124	128.79	0.438	7/16			1,190
		27.062	137.83	0.469	15/32			1,270
		27.000	146.85	0.500	1/2			1,360

* Plain end.
† Standard weight.

TABLE 5—*Physical Data for Mill-Type Pipe (contd.)*

Nominal Size *in.*	Outside Diam. *in.*	Inside Diam. *in.*	Weight per Linear Foot* *lb*	Wall Thickness *in.*		Grade X42
				Decimal	Fractional	Test Pressure *psi*
30	30.000	29.500	79.43	0.250	1/4	630
		29.438	89.27	0.281	9/32	710
		29.376	99.08	0.312	5/16	790
		29.312	108.88	0.344	11/32	870
		29.250	118.65	0.375	3/8	950
		29.188	128.40	0.406	13/32	1,030
		29.124	138.13	0.438	7/16	1,110
		29.062	147.84	0.469	15/32	1,190
		29.000	157.53	0.500	1/2	1,270
32	32.000	31.500	84.77	0.250	1/4	600
		31.438	95.28	0.281	9/32	670
		31.376	105.76	0.312	5/16	740
		31.312	116.22	0.344	11/32	820
		31.250	126.66	0.375	3/8	890
		31.188	137.08	0.406	13/32	960
		31.124	147.48	0.438	7/16	1,040
		31.062	157.86	0.469	15/32	1,110
		31.000	168.21	0.500	1/2	1,190
34	34.000	33.500	90.11	0.250	1/4	560
		33.438	101.28	0.281	9/32	630
		33.376	112.43	0.312	5/16	700
		33.312	123.56	0.344	11/32	770
		33.250	134.67	0.375	3/8	840
		33.188	145.76	0.406	13/32	910
		33.124	156.82	0.438	7/16	980
		33.062	167.87	0.469	15/32	1,050
		33.000	178.89	0.500	1/2	1,120
36	36.000	35.500	95.45	0.250	1/4	530
		35.438	107.29	0.281	9/32	600
		35.376	119.11	0.312	5/16	660
		35.312	130.90	0.344	11/32	730
		35.250	142.68	0.375	3/8	790
		35.188	154.43	0.406	13/32	860
		35.124	166.17	0.438	7/16	930
		35.062	177.88	0.469	15/32	990
		35.000	189.57	0.500	1/2	1,060

* Plain end.

Section 4—Hydrostatic Tests

Sec. 4.1—Mill Inspection Hydrostatic Test

Each length of pipe shall withstand, without leakage, a mill inspection hydrostatic test to at least the pressure shown in Table 5. Sizes larger than shown in Table 5 shall be tested to at least the pressure specified by the purchaser. Test pressures for all sizes of seamless pipe and for welded pipe in sizes 18 in. and smaller shall be held for not less than 5 sec. Test pressures for welded pipe in sizes 20 in. and larger shall be held for not less than 10 sec. For threaded-and-coupled pipe, the test shall be applied with the couplings made handling-tight, or made up power-tight if power-tight makeup is specified on the purchase order, except that 20-in. pipe and larger may be tested in the plain-end condition.

Sec. 4.2—Special Sections

4.2.1. Special sections and fittings made from pipe manufactured to this standard need not be hydrostatically tested.

4.2.2. All special sections and fittings not made from pipe manufactured to this standard shall be subjected to a hydrostatic test at a pressure * specified by the purchaser.

Section 5—Circumferential Welding of Straight Pipe Lengths

Sec. 5.1—Method

Welding of any type generally recognized as sound commercial practice shall be permitted.

Sec. 5.2—Workmanship

5.2.1. The ends of the pipe to be welded together shall be prepared in accordance with the requirements of the process used. The completed length shall be straight, within limits specified in this standard.

5.2.2. The weld shall have a substantially uniform cross section throughout the circumference of the pipe. The crowned surface shall at no point be below the outside surface of the parent metal, nor shall the crown at any point rise above the outside surface of the pipe more than $\frac{1}{8}$ in. Finished lengths of mill pipe, when so stipulated, shall permit the passage of a drift $\frac{1}{8}$ in. less than the nominal inside diameter of the pipe for sizes up to but not including $8\frac{5}{8}$ in.; $\frac{5}{32}$ in. on sizes $8\frac{5}{8}$–14 in.; and $\frac{3}{16}$ in. on sizes 16–20 in.

Section 6—Manual Metallic-Arc Repair Welding

Sec. 6.1—Procedure

All manual metallic-arc repair welds shall be made according to a tested procedure and by a repair welder qualified in accordance with Sec. 6.2 and Sec. 6.3, except that, at the option of the manufacturer, the test specified in the latest edition of the following publications may be substituted: API 1104 (Standard for Field Welding of Pipelines), ASA B31.1 (American Standard Code for Pressure Piping, Sec. 6), and ASME Boiler and Pres-

* The hydrostatic test pressures are mill inspection test pressures. They are not intended as a basis for design, and do not necessarily have any direct relationship to working pressures.

sure Vessel Code, Sec. IX. Test welds may be made either on plate stock or on pipe stock at the option of the manufacturer. The manufacturer shall maintain a record of the procedure and performance test results.

Sec. 6.2—Procedure Tests

Manual metallic-arc repair welding procedure tests shall be required on two specimens of every grade and on material at least as thick as the pipe on which repair welds are to be made. The transverse butt weld tensile test and either the longitudinal weld tensile-elongation test or the transverse guided weld bend test shall be made, except that the manufacturer shall have the option set forth in Sec. 6.1 above.

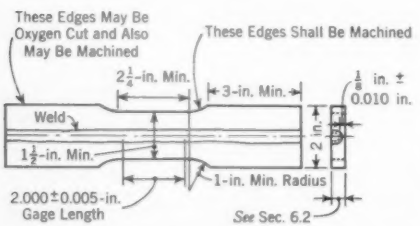

Fig. 4. Tensile-Elongation Test Specimen

The weld reinforcement shall be removed.

6.2.1. *Transverse butt-weld tensile test.* The transverse butt-weld tensile test specimen shall be approximately 1½ in. wide and shall have the transverse manual metallic-arc butt weld perpendicular to the longitudinal axis at the center of the test specimen. The weld reinforcement shall be removed from both faces. The ultimate tensile strength shall be at least equal to the minimum specified for the grade.

6.2.2. *Longitudinal-weld tensile-elongation test.* The longitudinal-weld tensile-elongation test specimen shall conform to Fig. 4. The weld shall be made in a groove as shown. The elongation after complete rupture of the test specimen in tension shall be at least equal to the minimum elongation specified for the grade.

6.2.3. *Transverse guided weld bend test.* The transverse guided weld bend test specimen shall conform to Fig. 5. The weld shall be made in a groove as shown. Specimens shall be bent approximately 180 deg in a jig substantially in accordance with Fig. 3 with the exposed surface of the weld in tension. The bend test shall be acceptable if no crack or other defect exceeding ⅛ in. in any direction is present in the weld metal or between the weld and the pipe metal after bending. Cracks which originate along the edges of the specimen during testing and which are less than ¼ in. measured in any direction shall not be considered detrimental.

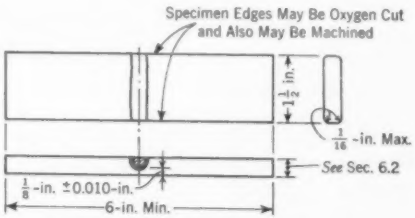

Fig. 5. Guided-Bend Test Specimen

The weld reinforcement shall be removed.

Sec. 6.3—Repair Welder's Performance Tests

Manual metallic-arc repair welder's performance tests shall be required on two specimens of every grade. If either of the two specimens fails to conform to the requirements specified, four retests shall be required immediately or two retests shall be required if the welder takes further instruction

in the practice before making a retest. All retests shall conform to the requirements specified. Further performance tests are not required unless the repair welder has not engaged in the tested repair welding procedure for a period of 3 months or more, or unless there is some specific reason to question his ability. Either of the following tests shall be made: the longitudinal weld tensile-elongation test (described in Sec. 6.2.2, above) or the transverse guided-weld bend test (described in Sec. 6.2.3, above).

Section 7—Tolerances

Sec. 7.1—Diameter

The outside diameter of pipe 1.900 in. and smaller shall not be more than 0.016 in. larger or 0.031 in. smaller than the specified outside diameter. The outside diameter of pipe larger than 1.900 in. shall not vary from the specified outside diameter by more than 1.0 per cent. Pipe $10\frac{3}{4}$ in. and smaller shall not be more than $\frac{1}{64}$ in. smaller than the tabulated outside diameter for a distance of 4 in. from the end of the pipe and shall permit the passage over the ends, for a distance of 4 in., of a ring gage which has a bore $\frac{1}{16}$ in. larger than the tabulated outside diameter of the pipe. Pipe $12\frac{3}{4}$–20 in. shall not be more than $\frac{1}{32}$ in. smaller than the tabulated outside diameter for a distance of 4 in. from the end of the pipe and shall permit the passage over the ends, for a distance of 4 in., of a ring gage which has a bore $\frac{3}{32}$ in. larger than the tabulated outside diameter of the pipe. At the option of the manufacturer, the minimum outside diameter of pipe in sizes 20 in. and smaller may be based on circumferential measurements. Pipe 22 in. and larger shall not be more than $\frac{1}{32}$ in. smaller nor more than $\frac{3}{32}$ in. larger than the tabulated outside diameter for a distance of 4 in. from the end of the pipe, based on circumferential measurements.

Sec. 7.2—Wall Thickness

For pipe in sizes 18 in. and smaller, the wall thickness shall not be more than 15.0 per cent greater than or 12.5 per cent less than the specified thickness. For pipe in sizes 20 in. and larger the wall thickness shall not be more than 15.0 per cent greater than or 10.0 per cent less than the specified thickness.

Sec. 7.3—Weight

The weight per foot of single lengths of pipe of all sizes in a regular-weight series shall not be more than 10.0 per cent greater than or 3.5 per cent less than the specified weight. The weight of carload lots of pipe in all sizes shall not be more than 1.75 per cent less than the specified weight.

Sec. 7.4—Length

7.4.1. *Straight pipe sections.* For all classes of pipe, when ordered to a specified length, the actual length shall not vary from the specified length by more than $\frac{1}{8}$ in. Unless otherwise agreed upon between the purchaser and the manufacturer, pipe shall be furnished in single random lengths or double random lengths as specified on the purchase order. If single random lengths are specified, the average length shall not be less than $17\frac{1}{2}$ ft, and no

piece shall be shorter than 9 ft. If double random lengths are specified, the average length shall not be less than 35 ft, not more than 10 per cent of the lengths shall be shorter than 26¼ ft, and no piece shall be shorter than 14 ft. If the average length agreed upon is in excess of 20 ft, not more than 10 per cent of the lengths shall be shorter than 75 per cent of the average length agreed upon, and no length shall be shorter than 40 per cent of the average length agreed upon.

7.4.2. *Special sections.* For special sections, such as elbows, wyes, tees, reducers, and closure pieces, the length tolerance shall be that shown in the drawings.

Sec. 7.5—Straightness

Finished pipe shall be reasonably straight for the application of interior lining.

Section 8—Pipe Ends

Sec. 8.1—Ends for Mechanical Couplings

8.1.1. Plain ends for use with mechanical couplings shall be square cut or beveled and the inside and outside edge burrs shall be removed. The pipe shall be sufficiently free from indentations, projections, or roll marks at each end to make a tight joint.

8.1.2. Ends for other types of mechanical couplings shall have tolerances within the limits required by the manufacturer of the coupling to be used.

Sec. 8.2—Ends for Field Butt Welding

8.2.1. For pipe of wall thickness ¼ in. or greater for field butt welding, the ends shall be beveled on the outside, on the inside, or from both sides, as specified, to an angle of 30 deg, with a maximum plus tolerance of 5 deg and no minus tolerance. It shall be understood that the angle of the bevel is measured from a line drawn perpendicular to the axis of the pipe. The width of the root face at the end of the pipe shall be $\frac{1}{16}$ in. with a tolerance of $\frac{1}{32}$ in.

8.2.2. For pipe of wall thickness less than ¼ in. for field butt welding, the ends need not be beveled.

Sec. 8.3—Bell-and-Spigot Ends With Rubber Gasket

For bell-and-spigot ends for use with a rubber gasket, the difference in measurement between the outside circumference of the spigot and the inside circumference of the bell shall be no less than 0.060 in. and no greater than 0.200 in.

Sec. 8.4—Threaded Ends

Threaded ends shall conform to the threading requirements specified in Sec. IX of API 5L. One end of each length of threaded pipe shall be provided with a coupling, and the other end with thread protection, both conforming to the requirements of Sec. VIII of API 5L. Couplings shall be screwed to the pipe handling-tight except that they shall be applied power-tight if so specified on the purchase order. A high-grade thread compound shall be applied to cover the full surface of either the coupling or pipe-engaged thread before making up the joint. All exposed threads shall be coated with a high-grade thread compound unless otherwise specified on the purchase order.

Sec. 8.5—Ends for Other Types of Joints

Ends for types of joints not covered above shall be made in accordance with the approved drawings. The other types of ends that may be used are: ends with slip joints (lap joints) for field welding, ends fitted with butt straps for field welding, ends for riveted field joints, bell-and-spigot ends for calked joints, plain ends fitted with flanges, and tapered ends for driven field joints.

Section 9—Marking and Delivery

Sec. 9.1—Marking

Each length of pipe shall be legibly marked by paint stenciling, die stamping, or hot-roll marking to show the manufacturer's name or mark, size of pipe, weight per foot, and grade (whether A, B, or X42).

Sec. 9.2—Delivery

Subject to agreement between the purchaser and the manufacturer, pipe sections shall be delivered in the order quired and shall be loaded in accordance with specifications set forth by the purchaser.

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ASA B58.1–1961
(AWWA A101–60)

AMERICAN STANDARD

for

VERTICAL TURBINE PUMPS

PUBLISHED BY AMERICAN WATER WORKS ASSOCIATION, INC.

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Latest Revisions to ASA B58.1

The latest changes in ASA B58.1 were approved by the American Standards Association on Jan. 31, 1961. The most important change was the inclusion of a new section (Part B) on submersible pumps. In addition, portions of the original standard (now Part A) were extensively revised, the major revisions occurring in Sec. A4.3 and A5.5.

Designation. The former designation, "B58.1–1955," has been changed to "B58.1–1961."

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ASA B58.1–1961
(AWWA A101–60)

American Standard for

Vertical Turbine Pumps

Part A—Line Shaft Vertical Turbine Pumps

Section A1—Scope and Purpose

This standard is recommended as a guide for users of the line shaft vertical turbine pump in selecting new equipment. The suggested standards are to be considered a minimum requirement for a first-quality vertical turbine pump, but do not preclude the use of more elaborate specifications on the part of either user or manufacturer, nor is it the intent to restrict the use of any equipment not meeting the requirements of this standard should the user not consider such compliance necessary.

This standard is applicable primarily to pumps that are constructed of accepted standard materials of the best quality and workmanship.

Section A2—Definitions

2.1. *A line shaft vertical turbine* pump is a vertical-shaft centrifugal or mixed-flow pump with rotating impeller or impellers, with discharge from the pumping element coaxial with the shaft. The pumping element is suspended by the conductor system which encloses a system of vertical shafting used to transmit power to the impellers, the prime mover being external to the flow stream. The unit is used for pumping from open pools or closed suction systems. A basic pump consists of three elements, defined as follows:

2.1.1. *The pump bowl assembly* is either a single or multistage, centrifugal or mixed-flow vertical pump with discharge coaxial with the shaft. It has open, semiopen, or enclosed impellers. Assemblies are constructed for use with either open or enclosed line shafts.

2.1.2. *The column-and-shaft assembly* consists of the column pipe which suspends the pump bowl assembly from the head assembly and serves as a conductor for the fluid from the pump bowl assembly to the discharge head. Contained within the column pipe is the line shaft which transmits the power from the driver to the pump shaft. The line shaft is supported throughout its length by means of bearings and may be enclosed in a shaft-enclosing tube and generally lubricated with oil, or it may be open and lubricated with the fluid being pumped.

2.1.3. *The head assembly* consists of the base from which the column and shaft assembly and the bowl assembly are suspended, the discharge head, which directs the fluid into the desired piping system, and the driver.

2.1.3.1. *The driver* is the mechanism mounted on the discharge head which transmits the power to the top shaft. It contains means for impeller

adjustment and provides a bearing to carry the thrust load. It may or may not be a prime mover.

2.1.3.2. *In underground discharge,* the discharge tee is separated from the head assembly and installed in the column pipe at the desired distance below the head assembly.

2.2. *Types of drivers* are defined as follows:

2.2.1. *The vertical hollow-shaft motor drive* is an electric motor having a motor shaft which has been bored on the center of its axis to receive the top shaft of the pump. Impeller adjustment is made at the upper end of the motor, and a means to carry the thrust on a bearing within the motor is provided.

2.2.2. *The vertical hollow-shaft right-angle gear drive* is a gear mechanism having a shaft which has been bored on the center of its axis to receive the top shaft of the pump. The horizontal shaft of a gear drive receives its power from the prime mover and, through a pair of bevel gears, transmits it to the top shaft. Impeller adjustment is made at the upper end of the gear drive, and a means to carry the thrust on a bearing within the gear drive is provided.

2.2.3. *The vertical hollow-shaft belted drive* is a flat- or V belt–driven mechanism having a shaft which has been bored on the center of its axis to receive the top shaft of the pump. Impeller adjustment is made at the upper end of the belted drive, and a means to carry the thrust on a bearing within the belted drive is provided.

2.2.4. *The flexible-coupling drive* is a mechanism having a thrust bearing capable of carrying the pump thrust, providing means of impeller adjustment, and having a flexible coupling. The top of this driver is designed to mount solid-shaft prime movers, incapable of supporting external thrust, including electric motors, steam turbines, radial engines, or any other type of prime mover having a solid shaft and suitable for mounting with the shaft in a vertical position.

2.2.5. *The combination drive* includes means for operating the pump with two or more drivers.

2.3. *The datum* shall be taken as the elevation of that surface from which the weight of the pump is supported. This is normally the elevation of the underside of the discharge head or head base plate.

2.4. *The setting* is the nominal distance in feet from the datum to the column pipe connection at the bowl assembly.

2.5. *The static water level* is the vertical distance in feet from the datum to the level of the free pool while no water is being drawn from the pool.

2.6. *The pumping water level* is the vertical distance in feet from the datum to the level of the free pool while the specified fluid flow is being drawn from the pool.

2.7. *Drawdown* is the difference in feet between the pumping water level and the static water level.

2.8. *Specific yield,* expressed in gpm (US gallons per minute) per foot of drawdown, is the rate of flow from the free pool, divided by the drawdown, in feet.

2.9. *The capacity of the pump* is the volume rate of flow (Q), expressed in gpm, produced by the pump, calculated for specified conditions.

2.10. *The pump speed of rotation* (N) is the rate of rotation of the pump shaft, expressed in rpm (revolutions per minute).

2.11. *Head* is a quantity used to express the energy content of the liquid per unit weight of the liquid, referred to any arbitrary datum. In

terms of foot-pounds of energy per pound of liquid being pumped, all head quantities have the dimension of feet of liquid.

2.11.1. *Head below datum* (h_b) is the vertical distance in feet between the datum and the pumping level.

2.11.2. *Head above datum* (h_a) is the head measured above the datum, expressed in feet of liquid, plus the velocity head (Sec. 2.11.3) at the point of measurement.

2.11.3. *Velocity head* (h_v) is the kinetic energy per unit weight of the liquid at a given section. Velocity head is specifically defined by the expression:

$$h_v = \frac{v^2}{2g}$$

2.11.4. *Suction head* (h_s) is the algebraic sum of the pressure head (measured at the elevation of the suction case lower connection) and the velocity head at that point. The value of the suction head is not required when the surface of the liquid being pumped is exposed to atmospheric pressure.

2.11.5. *Pump total head* (H) is the bowl assembly head (Sec. 2.11.6) minus the column loss (Sec. 2.12) and discharge head loss. This is the head generally called for in pump specifications.

2.11.5.1. *On open-suction installations,* it is the sum of the head below datum and the head above datum.

2.11.5.2. *On closed-suction installations,* it is the algebraic difference of the suction head, the distance between the suction case flange and the datum, and the head above datum.

2.11.6. *Bowl assembly head* (h_l) is the energy imparted to the liquid by the pump (expressed in foot-pounds per pound of liquid). It is the head of a pump installed with a minimum length of column and shaft, as in the manufacturer's laboratory.

2.11.6.1. *On open-suction installations,* it is the sum of the head below datum and the head above datum.

2.11.6.2. *On closed-suction installations,* it is the algebraic difference of the suction head, the distance between the suction case flange and the datum, and the head above datum.

2.12. *The column loss* (h_c) is the value of the head loss (expressed in feet) due to the flow friction in the column pipe. This value is subtracted from the bowl assembly head to predict the pump total head.

2.13. *The line shaft loss* (hp_s) is the power (expressed in horsepower) required because of the rotation friction of the line shaft. This value is added to the bowl assembly input (Sec. 2.14.3) to predict the pump input (Sec. 2.14.1).

2.14. *Power* is expressed in units of horsepower. One horsepower is equivalent to 550 ft-lb per second, 33,000 ft-lb per minute, 2,545 Btu per hour, or 0.746 kw.

2.14.1. *Pump input* is the power delivered to the line shaft, expressed in horsepower.

2.14.2. *Driver power input* is the power input to the driver, expressed in horsepower.

2.14.3. *Bowl assembly input* is the power delivered to the pump shaft, expressed in horsepower. It is the pump input of a pump installed with a minimum of column and shaft, as in the manufacturer's laboratory.

2.15. *Output* is defined as follows:

2.15.1. *Pump output* is defined as $\frac{QH}{3{,}960}$ for water having a specific weight of 62.4 lb per cubic foot. It is expressed in horsepower.

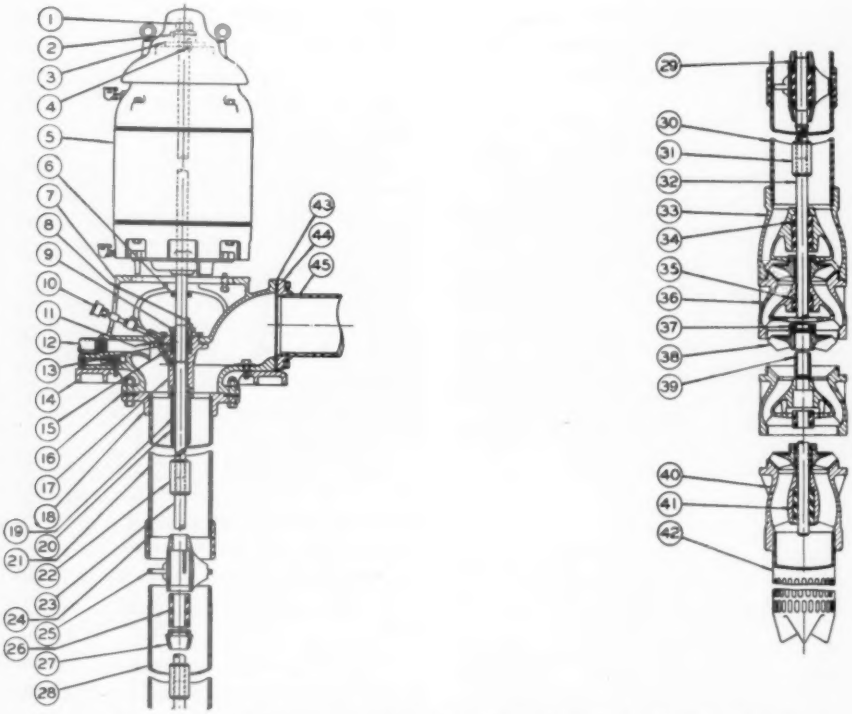

Fig. 1. Open Line Shaft Pump (Surface Discharge, Threaded Column and Bowls)

2.15.2. *Bowl output* is defined as $\frac{Qh_t}{3{,}960}$ for water having a specific weight of 62.4 lb per cubic foot. It is expressed in horsepower.

2.16. *Efficiency* is defined as follows:

2.16.1. *Pump efficiency* (E_p) is the ratio of pump output to pump input, expressed in per cent.

2.16.2. *Overall efficiency* (E) is the ratio of pump output to driver power input, expressed in per cent.

2.16.3. *Driver efficiency* (E_g) is the ratio of the driver output to the driver input, expressed in per cent.

2.16.4. *Bowl assembly efficiency* (E_l), is the ratio of the bowl output to the bowl assembly input, expressed in per cent.

Section A3—Nomenclature

Sec. A3.1—Standard Nomenclature

Table 1 lists the name of the part, together with its function and typical material. The material listed is intended to be typical only and does not constitute a recommendation. The part number refers to the numbers in Fig. 1 and 2.

Sec. A3.2—Order Form

A recommended specification form for use in purchasing deep well turbine pumps is given in Table 2.

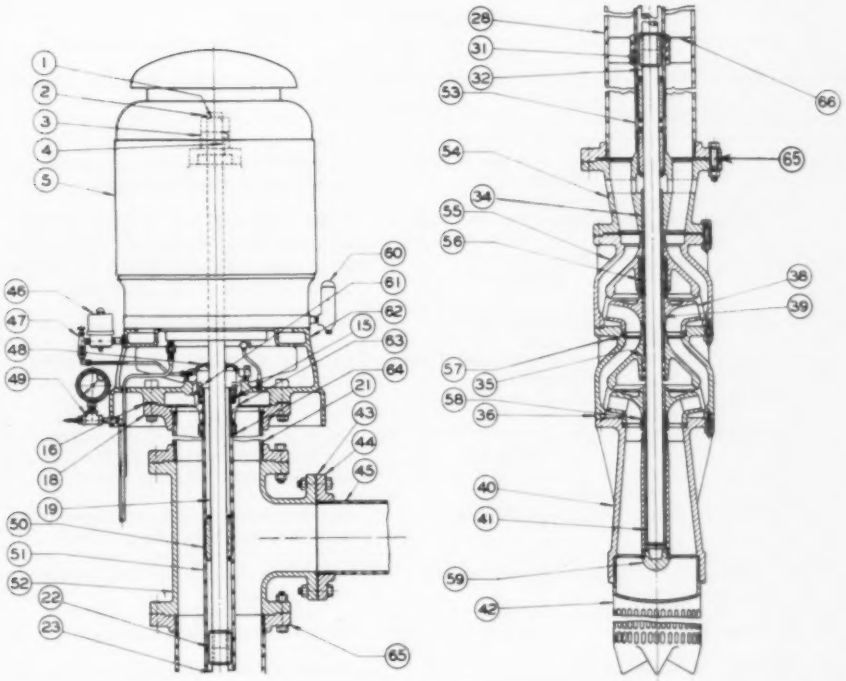

Fig. 2. Enclosed Line Shaft Pump (Underground Discharge, Flanged Column and Bowls)

Section A4—General Specifications

Sec. A4.1—General

4.1.1. *Descriptive matter.* The bidder shall submit, with his proposal, sufficient descriptive material or outline drawings to demonstrate compliance with these specifications, and a performance curve showing pump total head, pump input horsepower, and pump efficiency over the specified head range for the installed pump.

4.1.2. *Sanitary codes.* The pump shall conform to the sanitary codes governing the installation. The purchaser shall furnish, as a part of these specifications, all information necessary for the construction of the pump to meet these requirements.

4.1.3. *Pump base.* A suitable base of cast iron or fabricated steel shall be provided for mounting the driver and supporting the pump column. The (aboveground or below ground) discharge outlet shall be flanged, or a nipple with a companion flange shall be furnished for a 125-lb ASA B16.1 connection, as specified.

4.1.4. *Driver.* With electric power, the motor shall be of the full-voltage

TABLE 1

Standard Nomenclature

Part No.	Name of Part	Typical Material	Function of Part
1	Top shaft adjusting nut	brass or steel	means of adjusting impellers vertically by raising or lowering shaft
2	Adjusting-nut lock screw	steel or brass	locks adjusting nut in place so that adjustment cannot change while pump is in operation (furnished as simple pin or screwed or threaded pin)
3	Top drive coupling	semisteel	couples top shaft with motor rotor
4	Key for top drive coupling	cold-rolled steel	keys top shaft to top drive coupling
5	Motor		drives pump
6	Water slinger	neoprene, rubber, or steel	keeps packing box leakage from shooting directly into hollow shaft of motor or driver unit
7	Surface discharge head	cast iron	supports driver and pump column; discharges water from pump column
8	Stuffing box stud bolts and hexagonal nuts	brass or steel	fastened in stuffing box to adjust stuffing box gland
9	Stuffing box gland	cast iron or bronze	compresses and holds packing in place
10	Stuffing box lubrication fittings		conduct grease to packing and journal bearing
11	Stuffing box gasket		placed under seat of packing containers to prevent leakage
12	Prelubrication fittings		conduct water to keep water-lubricated bearings wet during starting cycle
13	Top shaft sleeve	monel or stainless steel	sleeve operating within packed area in top shaft on open line shaft pumps
14	Head base plate	cast iron or steel	plate or casting that supports discharge head and may become permanent part of foundation after initial installation
15	Packing		flexible material which can be compressed by stuffing box gland in stuffing box so as to prevent leakage of fluid being pumped
16	Top column flange gasket		seals joint between flange faces
17	Stuffing box	cast iron	guides shaft and holds packing
18	Top column flange	cast iron	couples column to discharge head

TABLE 1—*Standard Nomenclature (contd.)*

Part No.	Name of Part	Typical Material	Function of Part
19	Top shaft	steel	coupled to line shaft; connects latter to driver
20	Stilling tube	steel	suspended around top shaft from packing box to reduce flow of abrasive material into packing box
21	Top column pipe	steel	first section of column pipe below discharge
22	Line shaft coupling	steel	used to join all sections of line shafting throughout unit
23	Line shaft	steel	Those sections of line shafting between top shaft and pump shaft
24	Column pipe coupling	steel	couples sections of column pipe
25	Open line shaft bearing retainer	bronze	used to support line shaft bearing; generally located at end of each section of column pipe
26	Open line shaft bearing	rubber	bearing held in bearing retainer to guide line shafting of pump
27	Open line shaft bearing retainer cap	bronze	locks bearing within bearing retainer
28	Column pipe	steel	column pipe between top column and bottom column pipe; usually made of standard steel pipe
29	Open line shaft sleeve	monel or stainless steel	sleeve operating as journal for bearings
30	Bottom column pipe	steel	first section of column immediately above discharge case or discharge bowl
31	Pump shaft coupling	steel	connects bottom shaft to impeller shaft; may be tapped with two different thread diameters
32	Pump shaft	stainless steel	supports impellers; coupled to line shaft
33	Discharge bowl	cast iron	receives flow from top impeller and guides it to pump column
34	Top bowl bearing	bronze or rubber	supports portion of pump shaft
35	Intermediate bowl bearing	bronze or rubber	supports portion of pump shaft
36	Intermediate bowl	cast iron	guides flow received from impeller to next impeller above
37	Impeller collet lock nut	bronze	used to pull impeller on collet; locks collet in place

TABLE 1—*Standard Nomenclature (contd.)*

Part No.	Name of Part	Typical Material	Function of Part
38	Impeller	bronze or cast iron	pumping element; receives water and impels it centrifugally to bowl passage
39	Impeller lock collet	steel	locks impeller to shaft
40	Suction case	cast iron	receives water from well; guides to first impeller
41	Suction case bearing	bronze	supports bottom portion of pump shaft
42	Strainer	galvanized steel or bronze	keeps large foreign material out of pumps
43	Discharge companion flange gasket	rubberized cloth or rubber	seals joints between surface discharge head or underground elbow and companion flange
44	Discharge companion flange	cast iron	connects discharge pipe to integrally cast flanges on discharge head or underground discharge elbow
45	Discharge pipe	steel	conducts water away from pump.
46	Solenoid oil valve		starts oil flow to line shaft bearings when motor is started
47	Sight-feed oil valve		means of adjusting oil flow to line shaft bearings
48	Tubing tension nut cap	cast iron	covers top of oil tube to prevent entrance of dust
49	Water level indicator assembly		determines water level in well
50	Enclosed line shaft bearing	bronze	guides and supports shaft section may couple connecting sections of enclosing tube
51	Shaft-enclosing tube	steel	encloses line shaft
52	Underground discharge tee	cast iron	changes flow from vertical to horizontal when discharge is below surface; also forms part of column
53	Tubing adapter	cast iron or steel	encloses shaft; adapts standard tube size to off-standard tube size
54	Discharge case	cast iron	guides flow to pump column
55	Top bowl	cast iron	receives flow from top impeller and guides it to discharge case
56	Bypass seal		restricts leakage from bowls to oil tube; seals off bowl passages from enclosing tube

TABLE 1—*Standard Nomenclature (contd.)*

Part No.	Name of Part	Typical Material	Function of Part
57	Impeller seal ring	rubber, bronze, or hardened steel	provides water seal at impeller
58	Suction case sand collar	bronze	prevents sand from entering suction case bearing
59	Suction case plug	black iron	plugs suction case grease container
60	Oil gage assembly for motor bearings		shows level of oil in motor oil reservoir
61	Packing follower	cast iron	tightens packing around enclosing tube
62	Underground discharge head	cast iron	supports motor above foundation when discharge is below surface
63	Tubing tension nut	semisteel	maintains tension on shaft-enclosing tube
64	Lock nut for tubing tension nut	cast brass	locks tubing nut
65	Column flange	steel	joins sections of column pipe
66	Enclosing tube stabilizer	bronze or rubber	stabilizes shaft-enclosing tube

starting, vertical hollow-shaft squirrel-cage induction type, and shall comply with ASA C50.2. The connection to the pump shaft shall be through a coupling or clutch in the motor head. The motor shall be of the proper size to drive the pump continuously over the specified operating range without the load exceeding the service factor. The motor shall be rated as dripproof 40°C rise design with 1.15 service factor. (Standard motor voltages are 208, 220, 440, 550, 2,300.)

With an engine drive, the power shall be applied to the pump shaft through a right-angle gear set. The connection to the vertical shaft shall be through a coupling or clutch in the gear head. The horizontal shaft shall rotate in the same direction as the engine drive, and shall be connected to the engine by a flexible-shaft coupling.

An optional method of driving, for an engine or horizontal electric motor, shall be a belt head—either a flat belt on a modified cylindrical pulley, or a V belt on a V-groove pulley.

Rotation of the vertical shaft shall be counterclockwise when viewed from above.

A thrust bearing of ample capacity to carry the weight of all rotating parts plus the hydraulic thrust shall be incorporated into the driver as an integral part of it. The bearing shall be of such a size that the average life rating is no less than 5 years' continuous operation.

4.1.5. *Suction pipe and strainer.* A strainer, if required, shall have a

TABLE 2

*Suggested Specification Form for the Purchase of ASA Vertical Turbine Pumps**

1. Purchaser.....
2. Address .....
3. Installation site.....
4. Job No. ..... Item No. ..... Quote No.....
   P.O. No.....
5. No. required..... By ..... Date.....
6. Driver: Electric motor ..... Right-angle gear..... Belt.....
   Engine .....

Pump Operating Conditions

7. Capacity ..... gpm; Maximum speed ..... rpm
   Elevation at site ..... ft
8. Pumping level below ground level at rated capacity ..... ft
9. Pumping head above ground level, including discharge pipe friction ..... ft
10. Rated total pump head (Lines 8 plus 9, above) ..... ft
11. Operating range: Minimum total head ..... ft
    Maximum total head ..... ft
12. Pump setting ..... ft

Description of Well

13. Minimum inside diameter of well or casing ..... in., to a depth of ..... ft
14. Total depth of well ..... ft
15. Well straight to a depth of ..... ft (a well is considered straight if a 20-ft long cylinder equal to a bowl diameter will not bind when lowered to a depth equal to the pump setting)
16. Static water level below ground surface ..... ft
17. Pumping drawdown ..... ft at ..... gpm
18. Well developed to ..... per cent of rated pump capacity
19. Sand in water: None ..... Average ..... High ..... Unknown .....
20. Gas in water: None ..... Average ..... High ..... Unknown .....
21. Water corrosive: Yes ..... No .....
22. Corrosive substances .....
    Materials to resist corrosion .....

Driver Data

23. Electric power available .....: Maximum horsepower .....
    Volts..... Cycles ..... Phase.....
24. Other driver available .....: Maximum horsepower .....
    (Gas) (Gasoline) (Diesel) engine; Drive: (Direct) (Belt)
25. V-belt size .....: Groove type sheave diameter .....
    Flat belt width .....; Pulley diameter .....

Connections and Accessories

26. Discharge flange ..... in., 125-lb ASA standard threaded companion flange above-ground standard (if underground discharge desired, centerline shall be ..... ft below ground level)
27. Strainer required: Yes ..... No .....
28. Solenoid oiler required: Yes ..... No ..... Voltage available .....
29. Prelube water tank required: Yes ..... No .....
30. Automatic controls required: Time delay relay ..... Float switch .....

Pumps are to be furnished in accordance with ASA Standard B58.1, with the following exceptions:

* For submersible pumps, Item 6 would include electric motor only and Items 24, 25, and 28–30 do not apply.

net inlet area equal to at least three times the suction pipe area. The maximum opening shall be not more than 75 per cent of the minimum opening of the water passage through the bowl or impeller.

Sec. A4.2—Oil-Lubricated Pump and Column

4.2.1. *Pump bowls.* The castings shall be free of blow holes, sand holes, and other detrimental defects. The bowls shall be capable of withstanding a hydrostatic pressure equal to twice the pressure at rated capacity or 1½ times shutoff head, whichever is greater. Bowls may be equipped with replaceable seal rings on the suction side of enclosed impellers. The discharge case shall be provided with a means of reducing to a minimum the leakage of water into the shaft enclosing tube, and must have bypass ports of sufficient area to permit the escape of water that leaks through the seal or bushing.

4.2.2. *Impellers.* The impellers shall be of the enclosed or semiopen type, statically balanced. They shall be securely fastened to the impeller shaft with keys, taper bushings, or lock nuts. They shall be adjustable vertically by means of a nut in the motor head.

4.2.3. *Pump shaft.* The pump shaft shall be ground, and it shall be supported by bearings above and below each impeller. The minimum size of the shaft shall be determined by the following formula for steady loads of diffuser type pumps with shaft in tension due to hydraulic thrust:

$$D^3 = \frac{16}{\pi S}\sqrt{\left(\frac{FD}{8}\right)^2 + \left(\frac{396{,}000P}{2\pi N}\right)^2}$$

or:

$$S = \sqrt{\left(\frac{2F}{\pi D^2}\right)^2 + \left(\frac{321{,}000P}{ND^3}\right)^2}$$

or:

$$P = \frac{ND^3}{321{,}000}\left[S^2 - \left(\frac{2F}{\pi D^2}\right)^2\right]^{\frac{1}{2}}$$

in which D is the shaft diameter (in inches) at the root of the threads or the minimum diameter of any undercut; F is the total axial thrust (in pounds) of the shaft, including hydraulic thrust plus the weight of the shaft and all rotating parts supported by it; S is the combined shear stress (in pounds per square inch); P is the power transmitted by the shaft (in horsepower); and N is the rotation speed of the shaft (in revolutions per minute).

The maximum combined shear stress (S) shall not exceed 30 per cent of the elastic limit in tension or be more than 18 per cent of the ultimate tensile strength of the shafting steel used.

The straightness and machining tolerances shall be the same as those given under "Line Shafts" (Sec. 4.2.4).

4.2.4. *Line shafts.* The line shafts shall be ground, of carbon steel, and of the size that will conform to Sec. 4.2.3. For convenience, Tables 4 and 5 may be used when the shaft material complies with the physical properties set forth in Fig. 3–5. The shaft shall be furnished in interchangeable sections having a nominal length of 10 ft. To insure accurate alignment of the shafts, they shall be straight within 0.005-in. total indicator reading for a 10-ft section; the butting faces shall be machined square to the axis of the shaft; the maximum permissible error in the axial alignment of the thread axis with the axis of the shaft shall be 0.002 in. in 6 in. The line shaft shall be coupled with steel couplings, which shall be designed with a safety factor of 1½ times the shaft safety factor and shall have a left-hand thread to tighten during pump operation.

4.2.5. *Line shaft bearings.* The line shaft bearings, which also have integral couplings, shall be spaced not more than 5 ft apart. The maximum angle error of the thread axis to the bore axis shall be within 0.001 in. per inch of thread length. The concentricity of the bore to the threads shall be within 0.005 in. of the total indicator reading. The bearings must contain oil grooves or a separate bypass hole which will readily allow the oil to flow through and lubricate the bearings below.

4.2.6. *Shaft-enclosing tube.* The shaft-enclosing tube shall be made of extra-strong steel pipe in interchangeable sections not more than 5 ft in length. Each section shall be machined and threaded relative to accurately prepared diameters at extreme ends of the tube or by means of locating devices mounted thereon. The ends of the enclosing tube shall be square with the axis and shall butt to insure accurate alignment. The maximum angle error of the thread axis relative to the bore axis shall be 0.001 in. per inch of thread length. The enclosing tube shall be stabilized in the column pipe by stabilizers.

4.2.7. *Discharge column pipe.* The pipe size shall be such that the friction loss will not exceed 5 ft per 100 ft, based on the rated capacity of the pump. The pipe shall be furnished in interchangeable sections having a nominal length of 10 ft; shall be of standard weight, conforming to the specifications in Table 3; and shall be connected by threaded-sleeve couplings. The ends of each section of pipe may be faced parallel and machined with threads to permit ends to butt, or they may be fixed with ASA standard tapered pipe threads.

4.2.8. *Discharge head assembly.* At the surface discharge head or underground discharge head, a proper lubrication system must be installed; it shall consist of a manually operated sight-feed drip lubricator and an oil reservoir of ample capacity, constructed as an integral part of the head or as a separate auxiliary unit. A tubing tension nut shall be installed in the head to allow tension to be placed on the shaft enclosing tube. Provision must be made for sealing off the threads at the tension nut.

Sec. A4.3—Water-Lubricated Pump and Column

4.3.1. *Pump bowls.* The castings shall be free of blow holes, sand holes, and other detrimental defects. The bowls shall be capable of withstanding a hydrostatic pressure equal to twice the pressure at rated capacity or $1\frac{1}{2}$ times shutoff head, whichever is greater. Bowls may be equipped with replaceable seal rings on the suction side of enclosed impellers.

4.3.2. *Impellers.* The impellers shall be of the enclosed or semiopen type, statically balanced. They shall be securely fastened to the impeller shaft with keys, taper bushings, or lock nuts. They shall be adjustable vertically by means of a nut in the motor head.

4.3.3. *Pump shaft.* The pump shaft shall be ground, and it shall be supported by bearings above and below each impeller. The minimum size of the shaft shall be determined by the following formula for steady loads of diffuser type pumps with shaft in tension due to hydraulic thrust:

$$D^3 = \frac{16}{\pi S}\sqrt{\left(\frac{FD}{8}\right)^2 + \left(\frac{396{,}000P}{2\pi N}\right)^2}$$

or:

$$S = \sqrt{\left(\frac{2F}{\pi D^2}\right)^2 + \left(\frac{321{,}000P}{ND^3}\right)^2}$$

or:

$$P = \frac{ND^3}{321{,}000}\left[S^2 - \left(\frac{2F}{\pi D^2}\right)^2\right]^{\frac{1}{2}}$$

in which D is the shaft diameter (in inches) at the root of the threads or the minimum diameter of any undercut; F is the total axial thrust (in pounds) of the shaft, including hydraulic thrust plus the weight of the shaft and all rotating parts supported by it; S is the combined shear stress (in pounds per square inch); P is the power transmitted by the shaft (in horsepower); and N is the rotation speed of the shaft (in revolutions per minute).

The maximum combined shear stress (S) shall not exceed 30 per cent of the elastic limit in tension or be more than 18 per cent of the ultimate tensile strength of the shafting steel used.

The straightness and machining tolerances shall be the same as given under "Line Shafts" (Sec. 4.3.4).

4.3.4. *Line shafts.* The line shafts the size that will conform to Sec. 4.3.3. For convenience, Tables 4 and 5 may be used when the shaft material com plies with the physical properties set forth in Fig. 3–5. The shaft shall be furnished in interchangeable sections having a nominal length of 10 ft. To insure accurate alignment of the shafts, they shall be straight within 0.005-in. total indicator reading for a 10-ft section; the butting faces shall be machined square to the axis of the shaft; the maximum permissible error in the axial alignment of the thread axis with the axis of the shaft shall be 0.002 in. in 6 in. The line shaft shall be coupled with steel couplings, which shall be designed with a safety factor of 1½ times the shaft safety factor and shall have a left-hand thread to tighten during pump operation. The shaft shall be provided with a noncorrosive wearing surface at the location of each guide bearing.

4.3.5. *Line shaft bearings.* The shaft bearings shall be designed for vertical turbine pump service, to be lubricated by the liquid pumped. They shall be mounted in bearing retainers which shall be held in position in the column couplings by means of the butted ends of the column pipes. The bearings shall be spaced at intervals of not more than 10 ft.

4.3.6. *Discharge column pipe.* The pipe size shall be such that the friction loss will not exceed 5 ft per 100 ft, based on the rated capacity of the pump. The pipe shall be furnished in interchangeable sections having a nominal length of 10 ft; shall be of standard weight, conforming to the specifications in Table 3; and shall be connected with threaded sleeve type couplings. The ends of each section of column pipe shall be faced parallel and the threads machined to such a degree that the ends will butt, to insure proper alignment when assembled.

4.3.7. *Discharge head assembly.* The pump shall be provided with a discharge head of the surface or underground type, as required, and shall be provided with a shaft packing box and a renewable bronze bushing. The head shall also include a prelubrication connection to wet down the line shaft bearings adequately before starting the pump.

4.3.8. *Prelubrication.* Provisions shall be made by the manufacturer to prelubricate line shaft bearings adequately before the pump is started, on installations with a setting of more than 50 ft.

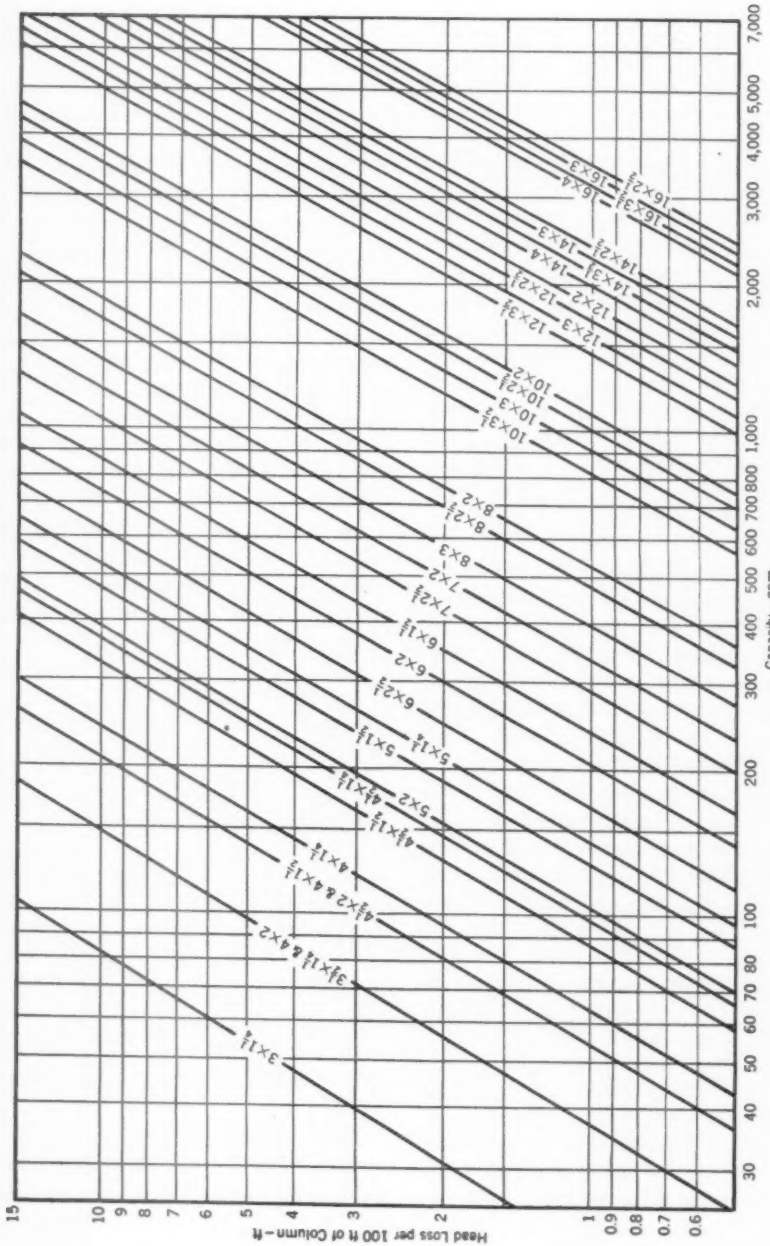

Fig. 3. Friction Loss Chart for Standard Pipe Column (See Note on Facing Page)

If manual control is used and a source of fresh water under pressure is not available, a prelubricating tank, with the necessary valves and fittings to connect it to the pump, shall be provided. The size of the tank shall be adequate to permit thorough wetting of all the line shaft bearings before the power is applied, with an adequate reserve for repeating the process in the event that the pump does not start the first time for any reason.

If an automatic system is used, bypass fittings or other suitable means shall be provided to bring the prelubricating water from ahead of the check valve into the prelubricating opening of the discharge head. This normally implies the use of a time delay relay in the starting system and a solenoid valve in the prelubricating line.

4.3.9. *Ratchets.* Water-lubricated vertical turbine pumps having a setting of 50 ft or more shall be provided with a nonreverse mechanism in the motor to protect the line shaft bearings from reverse rotation when the power is interrupted and the water empties from the discharge column.

Section A5—Engineering Data

Sec. A5.1—Discharge Column Pipe

Diameters and weights of standard discharge column pipe sizes are given in Table 3.

Sec. A5.2—Column Friction Loss

The column friction chart (Fig. 3) should be used to determine the loss in head due to column friction. This chart has been compiled from data on head losses where the flow is between the inside diameter of the column pipe and the outside diameter of the shaft-enclosing tube.

For open line shafting, the losses shown on Fig. 3 should be used by assuming the losses equal to those indicated on the chart for a shaft-enclosing tube of a size that would normally enclose the open line shaft in question.

Sec. A5.3—Discharge Head Loss

The discharge head loss chart (Fig. 4) should be used to determine the

Explanation of Fig. 3

Diagonals are labeled to show nominal diameters (in inches) of outer pipe column and inner shaft-enclosing tube. For the outer pipe columns, the calculations used in constructing the chart were based on inside diameters, which are close to the nominal sizes for pipe up to and including 12 in. (for example, 10 in. = 10.2-in. ID); in sizes 14 in. and larger, the diameters shown are equivalent to the outside diameter of pipe ⅜-in. wall thickness (for example, 16 in. = 15¼-in. ID). For the inner columns (shaft-enclosing tubes), the calculations were based on the outside diameters of standard or extra-heavy pipe. Thus, "8 × 2" on the chart is actually 8.071 × 2⅜, and "16 × 3" is 15¼ × 3½. (Chart reprinted by permission of Hydraulic Institute, Inc.)

TABLE 3

Diameters and Weights of Standard Discharge Column Pipe Sizes

Nominal Size (ID) *in.*	OD *in.*	Weight per Foot (Plain Ends) *lb*
2½	2.875	5.79
3	3.500	7.58
3½	4.000	9.11
4	4.500	10.79
4½	5.000	12.54
5	5.563	14.62
6	6.625	18.97
7	7.625	22.26
8	8.625	24.70
9	9.625	28.33
10	10.750	31.20
12	12.750	43.77
14*	14.000	54.57
16*	16.000	62.58

* OD.

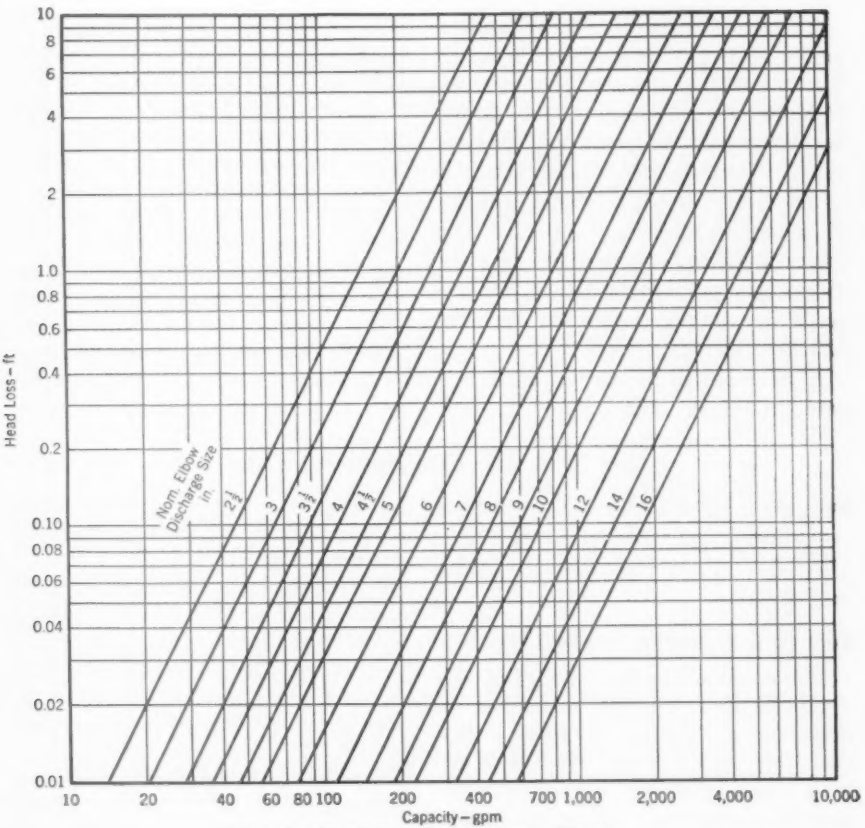

Fig. 4. Head Loss in Discharge Heads

hydraulic losses in the discharge head. Losses in discharge heads vary with the size of the head, the design of the head, and the size of tubing or shaft, column, and discharge pipe used. Figure 4 represents estimated average losses. Where extreme accuracy is imperative, actual loss measurements in the discharge head to be used—with the correct tubing or shaft, column, and discharge pipe—should be specified on the bid request by the purchaser.

Sec. A5.4—Mechanical Friction

The mechanical-friction chart (Fig. 5) should be used to determine the added horsepower due to mechanical friction in rotating the line shaft. The chart was compiled from test data submitted by representative turbine pump manufacturers. Variations in designs

Explanation of Fig. 5

The chart shows values for enclosed shaft with oil or water lubrication and drip feed, or for open shaft with water lubrication. For enclosed shaft with flooded tube, read two times the value of friction shown on the chart. (Chart reprinted by permission of Hydraulic Institute, Inc.)

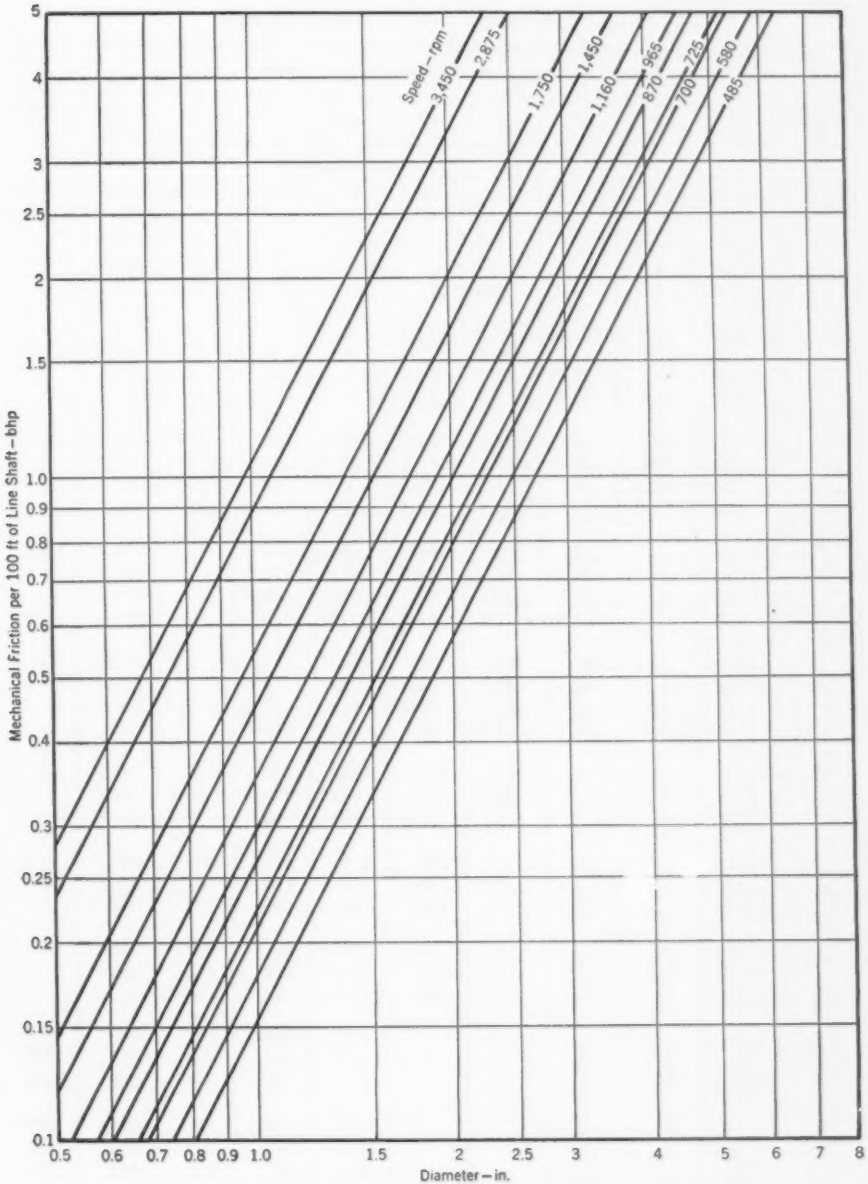

Fig. 5. Mechanical Friction in Line Shafts (See Note on Facing Page)

TABLE 4

Line Shaft Selection Chart for Type A Material *

Shaft Diameter *in.*	Speed *rpm*	Pump Thrust—*1,000 lb*								
		1	2	3	5	7.5	10	15	20	30
		Power Rating—*hp*								
3/4	3,500	22.8	21.7	18.6						
	1,760	11.4	10.9	9.3						
	1,160	7.5	7.2	6.2						
	860	5.6	5.3	4.6						
1	3,500	54.9	53.8	51.9	45.7					
	1,760	27.6	27.0	26.1	23.0					
	1,160	18.2	17.8	17.2	15.2					
	860	13.5	13.2	12.8	11.2					
1 3/16	3,500	97.2	96.5	95.0	90.0	79.8				
	1,760	48.8	48.5	47.7	45.2	40.1				
	1,160	32.2	32.0	31.5	29.8	26.4				
	860	23.9	23.7	23.4	22.1	19.6				
1 7/16	3,500		172	171	167	161	147			
	1,760		86.5	86.0	84.0	81.0	74.0			
	1,160		57.1	56.7	55.5	53.5	48.8			
	860		42.3	42.0	41.0	39.6	36.1			
1 1/2	3,500		196	194	191	183	174			
	1,760		98.5	97.9	96.0	92.0	87.4			
	1,160		65	64.5	63.2	60.6	57.6			
	860		48.1	47.8	46.9	45.0	42.7			
1 11/16	1,760			146	144	141	136	122		
	1,160			96.2	95.4	93.2	90.0	80.4		
	860			71.3	70.6	69.0	66.6	59.5		
1 15/16	1,760				228	225	221	209	191	
	1,160				150	148	145	138	126	
	860				111	110	108	102	93.5	
2 3/16	1,760				336	334	331	320	306	
	1,160				222	220	218	211	202	
	860				165	163	162	157	150	
2 7/16	1,760					473	469	461	448	410
	1,160					312	309	304	296	270
	860					231	229	226	220	200
2 11/16	1,760					620	617	611	598	564
	1,160					408	407	403	394	372
	860					303	302	299	293	276

* Steels with a minimum elastic limit of 23,300 psi and minimum ultimate tensile strength of 38,900 psi, such as SAE 1020.

TABLE 5

Line Shaft Selection Chart for Type B Material *

Shaft Diameter in.	Speed rpm	Pump Thrust—*1,000 lb*								
		1	2	3	5	7.5	10	15	20	30
		Power Rating—*hp*								
$\frac{3}{4}$	3,500	39.7	38.8	37.4	32.4					
	1,760	20.0	19.5	18.8	16.3					
	1,160	13.2	12.9	12.4	10.7					
	860	9.8	9.5	9.2	8.0					
1	3,500	94.5	93.8	93.0	89.5	82.5				
	1,760	47.5	47.2	46.7	45.0	41.5				
	1,160	31.3	31.1	30.8	29.7	27.3				
	860	23.2	23.1	22.9	22.0	20.3				
$1\frac{3}{16}$	3,500	167	167	166	163	157	149			
	1,760	84.0	84.0	83.5	82.0	79.0	75.0			
	1,160	55.4	55.4	55.0	54.1	52.1	49.4			
	860	41.0	41.0	40.7	40.0	38.6	36.6			
$1\frac{7}{16}$	3,500			296	294	289	283	264		
	1,760			149	146	145	142	133		
	1,160			98.3	97.6	96.0	94.0	87.6		
	860			72.7	72.3	71.0	69.5	64.8		
$1\frac{1}{2}$	3,500			336	334	330	324	306		
	1,760			169	168	166	163	154		
	1,160			111.2	110.7	109.2	107.2	101.4		
	860			82.6	82.1	81.1	79.6	75.2		
$1\frac{11}{16}$	1,760			252	251	248	246	239	227	
	1,160			166	165	164	162	157	150	
	860			123	122	121	120	117	111	
$1\frac{15}{16}$	1,760				393	392	390	382	373	345
	1,160				259	258	257	252	246	228
	860				192	192	191	187	182	169
$2\frac{3}{16}$	1,760				578	577	576	570	562	538
	1,160				382	381	380	376	371	355
	860				283	282	281	279	275	263
$2\frac{7}{16}$	1,760					816	815	810	802	781
	1,160					537	537	533	529	515
	860					398	398	395	392	381
$2\frac{11}{16}$	1,760						1,070	1,062	1,055	1,035
	1,160						703	700	696	682
	860						520	518	515	505

* Steels with a minimum elastic limit of 40,000 psi and a minimum ultimate tensile strength of 67,000 psi, such as American Iron & Steel Institute (AISI) C-1045.

used by individual manufacturers may affect the figures slightly.

Sec. A5.5—Line Shaft Selection

Line shaft selection shall be made in accordance with the following procedure, using Table 4 or 5, or should be calculated for the specific material used in accordance with Sec. 4.2.3.

5.5.1. Table 4 does not limit the maximum rotative speed of shafts, the maximum setting of shafts, or the bearing spacing used with the shafting.

5.5.2. Table 4 defines the maximum recommended horsepower for a given size of shaft, taking into account the effect of the hydraulic thrust of the pumping equipment and the weight of the shaft and suspended rotating parts. The table is applicable to any steel having a minimum elastic limit of 23,000 psi and a minimum ultimate tensile strength of 38,900 psi. Ratings listed in the table apply to steels purchased without specification of definite physical properties, such as SAE 1020.

5.5.3. Table 5 is similar to Table 4, except that it is applicable to a steel having a minimum elastic limit of 40,000 psi and a minimum ultimate tensile strength of 67,000 psi. Ratings listed in the table apply to AISI Type C-1045, annealed AISI Type 416 stainless steel, and others with similar physical properties.

5.5.4. Horsepower ratings shown in Tables 4 and 5 and calculated in accordance with Sec. 4.2.3 represent maximum loads and should not be increased by electric-motor service factors.

Section A6—Factory Inspection and Tests

Sec. A6.1—Performance Tests

6.1.1. The standard procedure for determining the performance of a vertical turbine pump by making a factory laboratory test of the bowl assembly and then calculating the anticipated field performance is described below. A performance test will be made only when specified in the purchaser's inquiry and order. The inquiry and order shall specify which of the following are required:

a. Standard running test
b. Witnessed running test
c. Shop inspection
d. Hydrostatic test of discharge head
e. Hydrostatic test of bowl assembly

If other tests are required, the purchaser shall describe them in detail.

6.1.2. The manufacturer shall notify the purchaser not less than 10 days prior to the date the pump or pumps will be ready for inspection or witness test.

Sec. A6.2—Standard Running Test

6.2.1. The pump bowl assembly will be operated from zero capacity to the maximum capacity shown on the performance curve submitted with the manufacturer's bid. Readings shall be taken at a minimum of five capacity points, including one point within ± 2 per cent of the design capacity specified on the request for bid.

The pump shall be operated at a speed within ± 5 per cent of the design speed. This does not apply to model or slow-speed tests described in Sec. 6.9.

6.2.2. At the conclusion of the test, three copies of the test data sheet and the anticipated field performance curve shall be supplied to the purchaser.

Sec. A6.3—Typical Laboratory Test Arrangement

Figure 6 shows a typical laboratory arrangement for the testing of a vertical turbine pump. A test laboratory will normally be constructed to provide favorable suction conditions for pump performance. If the purchaser plans to use the pump under questionable well or sump conditions and wishes the pump to be tested under these exact conditions, complete information should be included in the request for bid. If there is nothing stated in the bid with relation to required well or sump conditions, it shall be assumed that standard laboratory arrangements will be used.

Sec. A6.4—Capacity Measurement

The capacity of the pump shall be measured by means of a standard venturi tube, nozzle, orifice plate, or pitot tube traverse. The pump manufacturer shall supply evidence that the capacity-measuring device used has been properly calibrated, that it is in good condition, and that the pressure taps and piping are proper for the instrument being used and are essentially the same as during the calibration. Instruments which have not been calibrated should be geometrically similar to properly calibrated models.

A description of the application of fluid meters is contained in the ASME publication, "Fluid Meters—Their Theory and Application." A detailed description of the various meters and their application is given in Chapter B-2 of that publication, the physical constants and meter coefficients are indicated in Section C, and the discharge coefficient tolerances of the various meters are indicated in Chapter C-7.

The surface conditions, size, and length of the pipe preceding the fluid-measuring device are as important as the calibration of the device itself. Thus, piping should be in close conformity with that used when the instrument was calibrated or in accordance with the recommendations by the manufacturer of the fluid-measuring device.

Fluid manometers should be used for measuring the pressure differential across the meter.

Sec. A6.5—Head Measurement

All pump bowl assembly tests shall be made in open sumps, unless otherwise stated in the request for bid.

The pressure tap for head measurement shall be located in the discharge column not less than 2 ft above the pump bowl assembly. The pressure tap shall be at right angles to the pipe, free from burrs, and flush with the surface of the column pipe. The openings shall be of a diameter from $\frac{1}{8}$ to $\frac{1}{4}$ in. and of a length not less than twice the diameter.

As an alternative method, the pressure tap for head measurement can also be located not less than ten diameters downstream from the discharge elbow of the test pump. (The elbow to be furnished with the pump shall be used.) When the pump head is measured at this point, no deduction for elbow loss need be made in anticipating field performance.

For head measurements of 36 ft or less, only fluid manometers shall be used. For head measurements in excess of 36 ft, calibrated Bourdon or other gages with equivalent accuracy and reliability can be used. All gages shall be calibrated before and after each series of tests.

Sec. A6.6—Velocity Head

The average velocity in the pump column used to determine the velocity head shall be calculated from dimensions obtained by actual measurement of the pipe and shaft or enclosing-tube diameter at the point of pressure measurement.

If the pressure measurement is made downstream from the discharge elbow, the velocity head shall be obtained from actual measurement of the inside diameters of the discharge pipe at the point where the pressure tap is located.

Sec. A6.7—Horsepower Input

The power input to the pump shall be determined with a vertical dynamometer or a calibrated electric motor.

The torque of the dynamometer shall be measured by means of a calibrated springless scale, calibrated strain gage, or other device of equivalent accuracy.

Squirrel-cage induction motors (when operated at greater than half the nameplate rating), direct-current motors, synchronous motors, or wound-rotor induction motors with short-circuited secondary resistance may be employed for the determination of shaft input, provided the efficiencies or losses have been ascertained by an AIEE test or its equivalent.

Where the specifications call for an overall efficiency guarantee, the actual job motor can be used without calibration and the overall bowl assembly efficiency calculated directly.

Calibrated laboratory type electric meters and transformers shall be used to measure power input to all motors.

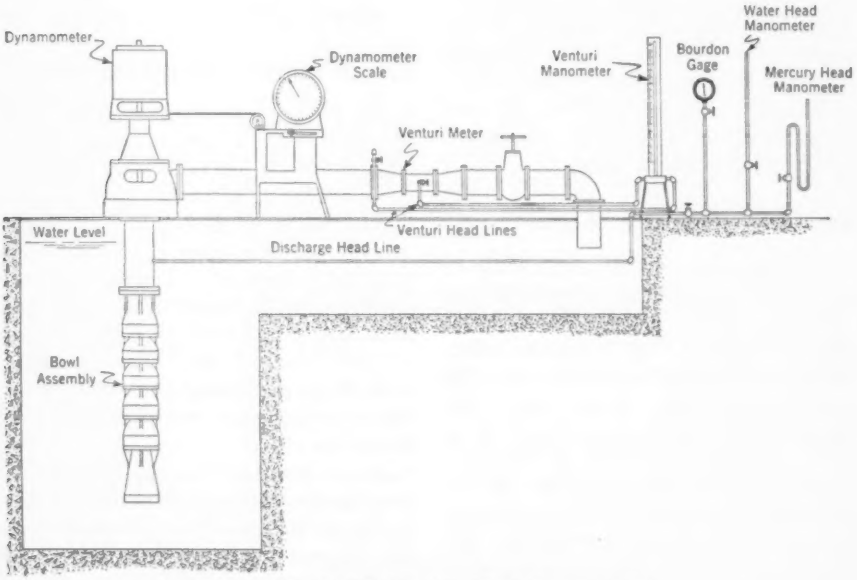

Fig. 6. **Typical Laboratory Test Arrangement**

Sec. A6.8—Measurement of Speed

The rotating speed of the pump shall be obtained by a hand counter, electronic computer, or a stroboscope counting slip. It should be noted that

an accurate speed reading is important in determining power input when a dynamometer is used. Accuracy is less important when a calibrated motor is used.

Sec. A6.9—Large-Pump Tests

6.9.1. On all pump bowl assemblies where the horsepower is not in excess of 200 and the bowl diameter is not in excess of 20 in., the actual pump shall be tested in the manufacturer's laboratory.

6.9.2. If the horsepower exceeds 200, it shall be permissible for the manufacturer to test only the number of stages of the unit which come within this power requirement. If a test is made on a limited number of stages, no increase in efficiency shall be permitted for an increased number of stages when predicting the final performance of the complete bowl assembly. The head and horsepower shall be increased in direct proportion to the number of stages in the final assembly, compared with the number of stages used in the laboratory test.

6.9.3. When the size of the bowls exceeds 20-in. OD, a laboratory test on a model pump, homologous with the actual unit, may be used as a basis for the determination of the performance of the actual unit. (In general, when contract guarantees are to be based on model tests, the contract should specify model performance rather than inferred actual-unit performance. In the absence of this provision, allowance for the scale effect, if any, shall be agreed upon in writing by the representatives of both parties prior to the tests.)

The model pump shall be run at a speed sufficient to develop a head per stage at least equal to that of the actual unit, so that the velocities will equal or exceed those of the actual unit; or the manufacturer must submit evidence that a single-stage model does not cavitate under specified field suction conditions when operated at a speed such that the velocities will equal or exceed those of the actual unit.

6.9.4. On bowl assemblies which have an OD exceeding 20 in. or which require more than 200 hp, it will be permissible to test the actual bowl assembly at a speed slower than that at which the pump will run in the field rather than make a model test. No efficiency increase will be allowed when the performance in the slow-speed test is translated into that at full speed. The manufacturer must submit evidence that a single-stage bowl assembly or a single-stage model does not cavitate under specified field suction conditions when operated at a speed such that the velocities will equal or exceed those of the actual unit.

6.9.5. All large bowl assembly full-speed tests or model tests must be conducted with the identical submergence that will exist in the field, as shown on the request for bids.

Sec. A6.10—Hydrostatic Tests

6.10.1. A standard hydrostatic test on the pump bowl assembly shall be made at 1½ times the shutoff head developed by the pump bowl assembly or at twice the rated head, whichever is greater.

6.10.2. A standard hydrostatic test on the discharge head shall be made at the pressure defined in Sec. 6.10.1, less the pump setting specified on the order.

Sec. A6.11—Recording and Computation of Test Results

6.11.1. All instrument test readings, as well as corrected readings, shall be recorded on the test sheet. Complete data concerning the pump,

driver, and instrument identification shall also be recorded.

6.11.2. All test results shall be translated into performance at the anticipated speed of the driver at the design point, by these formulas:

$$Q = Q_t \frac{N}{N_t}$$

$$H = H_t \left(\frac{N}{N_t}\right)^2$$

$$\text{bhp} = \text{bhp}_t \left(\frac{N}{N_t}\right)^3$$

in which Q is capacity (gpm), H is head (ft of water), bhp is brake horsepower, N is anticipated operating speed (rpm), and subscript "$_t$" indicates test values.

6.11.3. The bowl assembly input horsepower, when measured by a vertical dynamometer, is found from the expression KFN_t, in which K, the dynamometer constant, equals $\frac{2\pi L}{33{,}000}$, L is the length (ft) of the lever arm, F is the net force (lb) at the end of the lever arm, and N is the speed (rpm) of the driver when the test reading is taken.

6.11.4. The motor power input, in horsepower, is the corrected kilowatt input to motor divided by 0.746.

6.11.5. The bowl assembly input horsepower to a pump driven by an electric motor is:

$$\frac{\text{kw}}{0.746} E_g$$

kw being the corrected kilowatt input to motor and η_g the motor efficiency from the calibration curve.

6.11.6. The pump bowl assembly efficiency (E_l) is:

$$\frac{Qh_l}{3{,}960 \times (\text{bhp})}$$

in which Q is the measured capacity (gpm); h_l is the bowl assembly head (ft), including velocity head; and bhp is the brake horsepower to the pump bowl assembly, measured by dynamometer or calibrated motor.

6.11.7. The pump total head (H), in feet, is found by:

$$H = h_l - h_c - h_e$$

in which h_l is the bowl assembly head (ft), from test; h_c is the column loss (ft), obtained from Fig. 3 and based on complete pump setting; and h_e is the discharge head loss (ft), from Fig. 4 or actual test.

6.11.8. The pump input horsepower equals the bowl assembly input horsepower plus the line shaft loss in horsepower. The bowl assembly input horsepower is calculated from test, as in Sec. 6.11.3 or 6.11.5. The line shaft loss is obtained from Fig. 4 and based on complete pump setting.

6.11.9. The pump efficiency (E_p) is found by:

$$E_p = \frac{QH}{3{,}960 \times \text{pump input hp}}$$

in which the pump total head (H) is obtained from Sec. 6.11.7 and the power input from Sec. 6.11.8.

6.11.10. The overall efficiency (E) is the pump efficiency (E_p) multiplied by the motor efficiency (E_g).

6.11.11. The complete pump total head, efficiency, and pump input horsepower should be plotted as ordinates on the same sheet against the capacity as abscissa to show the anticipated field performance of the complete pumps.

Sec. A6.12—Other Tests

For more complete tests, or for tests involving fluids other than water, refer to the ASME "Power Test Code for Centrifugal and Rotary Pumps" as applicable.

American Standard for

Vertical Turbine Pumps

Part B—Submersible Vertical Turbine Pumps

Section B1—Scope and Purpose

This standard is recommended as a guide for users of the submersible vertical turbine pump in selecting new equipment. It applies to pumps using a 7½-hp motor or larger. The suggested standards are to be considered a minimum requirement for a first-quality vertical turbine pump, but do not preclude the use of more elaborate specifications on the part of either user or manufacturer, nor is it intended to restrict the use of any equipment not meeting the requirements of this standard should the user not consider such compliance necessary.

This standard is applicable primarily to pumps that are constructed of accepted standard materials of the best quality and workmanship, and that handle cold, clear water, usually from an underground well.

Section B2—Definitions

In addition to the definitions given below, Sec. 2.3–2.12 and Sec. 2.14–2.17 of Part A (line shaft pumps) also apply to submersible pumps.

B2.1. *A submersible pump* is an integral combination of a vertical turbine pump, close coupled to an electric motor designed for sustained and continuous operation under water. The unit is suspended from a surface plate by the vertical discharge pipe and receives electrical energy through a submersible power cable. This type of pump has no line shaft, or shaft-enclosing tube. A basic pump consists of seven elements, defined as follows:

B2.1.1. *The pump bowl assembly* is a single or multistage, centrifugal or mixed-flow vertical pump with discharge coaxial with the shaft. It can have open, semiopen, or enclosed impellers.

B2.1.2. *The vertical discharge pipe* conducts water from the pump bowl assembly to the surface plate connection. It supports the pump and driver in the well and an electric cable, which carries current from the surface to the motor lead connection.

B2.1.3. *The head assembly* consists of a surface plate from which the vertical discharge pipe is suspended, contains provisions for the cable to pass through, and may include an elbow which directs the water into a piping system as required.

B2.1.4. *The driver* is a squirrel cage induction electric motor suspended below the interconnector at the bottom of the bowl assembly; it contains a bearing capable of carrying the pump hydraulic-thrust load and the weight of all rotating parts.

TABLE 6

Standard Nomenclature

Part No.	Name of Part	Typical Material	Function of Part
101	Top bowl flange	Cast iron	Connects pump to discharge pipe
102	Top or discharge bowl	Cast iron	Guides flow to discharge pipe
32	Pump shaft	Stainless steel	Transmits power to impellers
34	Top bowl bearing	Bronze or rubber	Guides top end of pump shaft
35	Intermediate bowl bearing	Bronze or rubber	Guides shaft at impellers
36	Intermediate bowl	Cast iron	Directs flow from impeller to next impeller above
42	Strainer	Galvanized steel or bronze	Prevents large objects from entering pump
38	Impeller	Bronze or cast iron	Imparts energy to water
39	Impeller lock collet	Steel	Locks impeller to shaft
40	Suction case	Cast iron	Directs water to first-stage impeller
110	Sand collar	Bronze	Restricts sand from entering bearing
111	Upper strainer interconnector bearing	Bronze	Guides lower end of pump shaft
112	Strainer interconnector	Cast iron	Connects suction bowl to interconnector and supports strainer
113	Lower strainer interconnector bearing	Bronze	Guides lower end of pump shaft
114	Interconnector	Cast iron	Connects strainer interconnector to motor; has splits or pocket to allow coupling connection
115	Pump-motor coupling	Stainless steel	Connects pump shaft to motor shaft
116	Welding discharge elbow	Steel	Connects vertical discharge pipe to discharge pipeline
117	Flanged discharge elbow	Cast iron	Connects vertical discharge pipe to discharge pipeline
118	Cable	Copper with synthetic-rubber or plastic insulation and protective jacket	Conducts electricity to motor
119	Cable clamp	Stainless steel or rubber	Fastens cable to column pipe
120	Motor cable splice (mechanical)	Metal or plastic	Joins motor leads with power cable
121	Discharge pipe coupling	Steel	Connects discharge pipe sections
122	Discharge pipe	Steel	Conducts water out of well
123	Conductor guard	Bronze or steel	Protects conductor
124	Cable terminal	Various	Secures motor cable into motor case
125	Submersible motor	Various	Drives pump
126	Suction interconnector bearing	Bronze or rubber	Guides lower end of pump shaft
127	Surface plate	Steel or cast iron	Supports pump, motor, and discharge pipe
128	Surface plate (sealed)	Steel or cast iron	Supports pump, motor, and discharge pipe and seals off well from contamination

TABLE 6—*Standard Nomenclature (contd.)*

Part No.	Name of Part	Typical Material	Function of Part
129	Surface plate gasket	Rubber or asbestos compound	Seals surface plate and well flange
130	Well flange	Steel or cast iron	Base plate to assure pump alignment and seal well casing
131	Cable seal gland	Bronze	Supports cable and seals between cable and surface plate
132	Terminal box	Cast iron	Provides enclosured means of connecting cable and surface wiring
133	Access hole plug	Steel	Provides access to well
134	Well vent connection	Steel	Makes provision for air vent for well
135	Suction interconnector	Cast iron	Connects motor to bottom intermediate bowl, acts as suction bowl, and supports strainer

B2.1.5. *The cable* is the conductor that conducts power from the surface to the motor terminal leads.

B2.1.6. *The splice* is the waterproof device connecting the power cable and the electric-motor leads or joining the cable below the surface.

B2.1.7. *The motor leads* conduct electricity between the cable and the motor windings.

Section B3—Nomenclature

Sec. B3.1—Standard Nomenclature

Table 6 lists the name of the part, together with its function and typical material. The material listed is intended to be typical only and does not constitute a recommendation. The part numbers refer to the numbers in Fig. 7 and 8.

Sec. B3.2—Order Form

A recommended specification form for use in purchasing vertical turbine pumps is given in Table 2.

Section B4—General Specifications

Sec. B4.1—General

B4.1.1. *Descriptive matter.* The bidder shall submit, with his proposal, sufficient descriptive material or outline drawings to demonstrate compliance with these specifications, and a performance curve showing pump total head, pump input horsepower, and pump efficiency over the specified head range for the installed pump.

B4.1.2. *Sanitary codes.* The pump shall conform to the sanitary codes governing the installation. The purchaser shall furnish, as a part of these specifications, all information necessary for the construction of the pump to meet these requirements.

Sec. B4.2—Submersible Motor

B4.2.1. *Materials.* Construction materials shall be suitable for their application from the standpoints of corrosion resistance and mechanical performance.

B4.2.2. *Design.* The motor shall be of the squirrel cage induction type, suitable for across-the-line starting and shall be capable of reduced-voltage starting. It shall be capable of continuous operation under water at the conditions specified.

B4.2.3. *Temperature.* The motor temperature rise shall conform to the latest NEMA standards for submersible motors.

B4.2.4. *Thrust bearing.* A thrust bearing of ample capacity to carry the weight of all rotating parts plus the hydraulic thrust shall be an integral part of the driver. The bearing shall be of such a size that the average life rating is based on 5 years' continuous operation. It shall also have ample capacity to permit the pump to operate for short periods with the discharge valve closed.

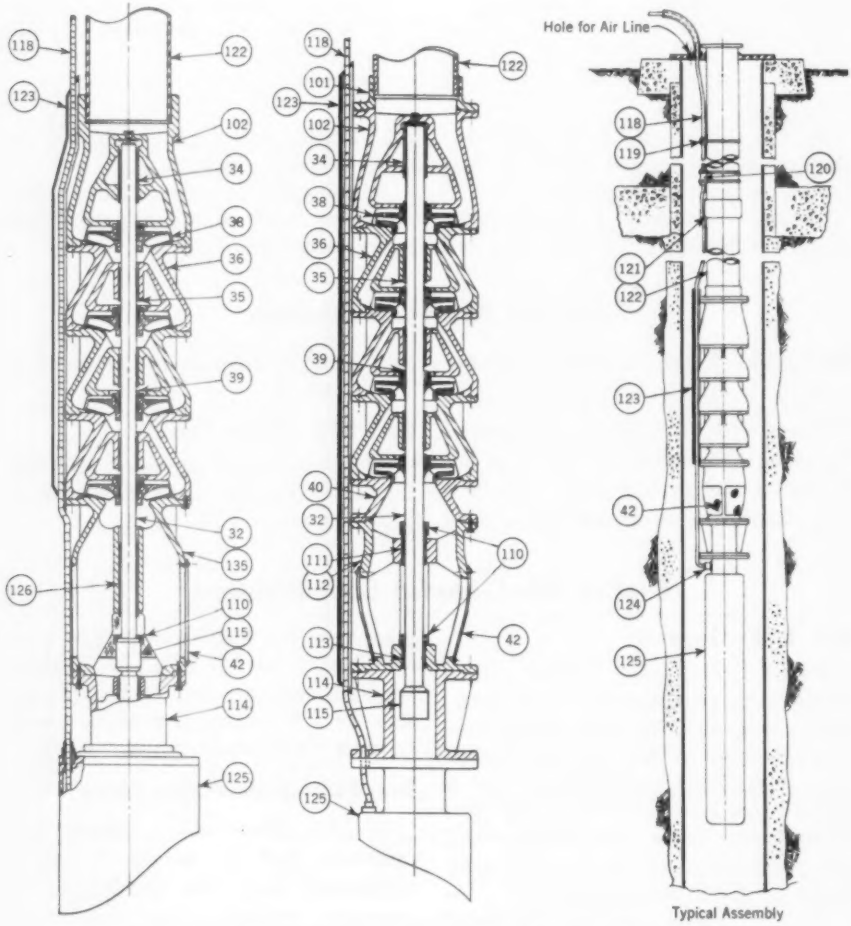

Fig. 7. Typical Submersible-Pump Assembly (Bowl Assemblies)

B4.2.5. *Foreign matter.* Suitable precautions shall be taken to restrict sand, silt, or foreign material from entering the motor.

B4.2.6. *Diameter.* The maximum motor diameter and the minimum inside diameter of the well shall be in such relationship that the maximum water velocity past the motor shall be 12 fps. For this purpose a minor irregularity in the motor shape, such as that caused by the cable connection, shall not be included in the motor diameter measurement.

Sec. B4.3—Submersible Cable

B4.3.1. *Conductors.* The cable shall be comprised of three or more separate conductors or a single cable assembly with three or more conductors. Stranding shall meet ASTM class designation standards *—Class B on No.

* The ASTM class designations referred to above are as follows:

Class B on No. 10 and smaller cable provides for at least 7 strands minimum.

Class C on No. 9 through No. 2 cables provides for at least 19 strands minimum.

Class C on No. 1 through 4/0 cable provides for at least 37 strands minimum.

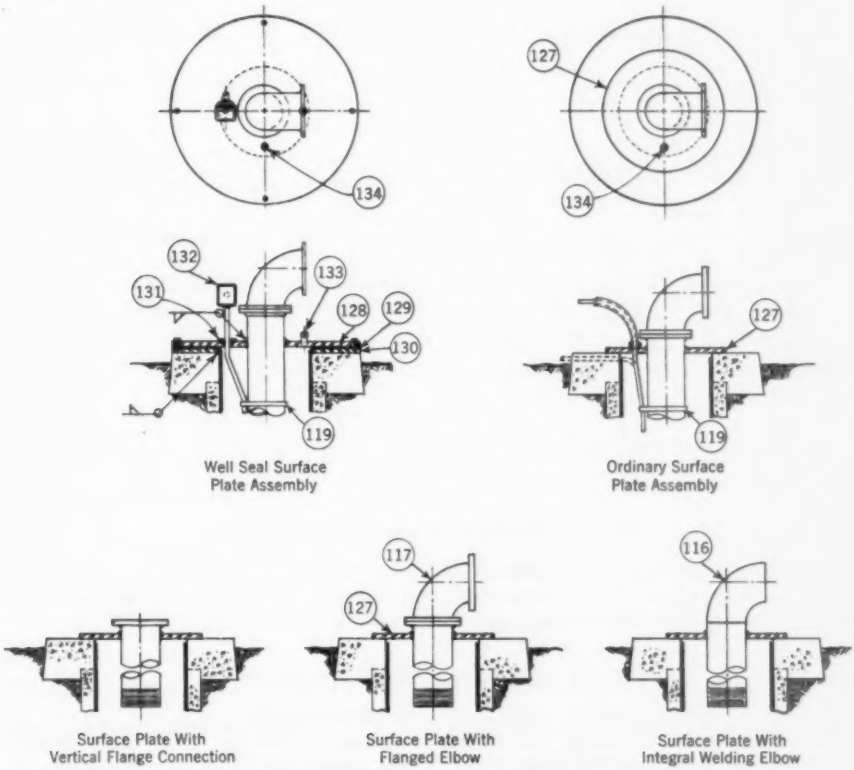

Fig. 8. Submersible-Pump Discharge Styles and Surface Plate Assemblies

Well seal surface plates are for use where well sealing is required; a flange must be welded to the casing by a continuous watertight weld or the plate must be grouted in place. Ordinary surface plates may be used where sanitary well seals are not required.

10 and smaller cable and Class C on No. 9 and larger cable. Each conductor shall be insulated by synthetic rubber or plastic insulation suitable for continuous immersion in water. When three or more single conductors are used, each must be jacketed. When a three or more conductor cable is used, it must be jacketed. The jacket material must be oil- and water-resistant synthetic rubber, metal, or other suitable mechanically protective material. The cable shall have a sufficient conductor area to meet the minimum requirement of the Insulated Power Cable Engineers Assn. (IPCEA) code for operation in air. (The connecting electric cable from the starting equipment to the surface plate shall meet the National Electrical Code or local codes, whichever may govern.)

B4.3.2. *Supports.* The cable shall be suitably supported from the column at a number of points adequate for the type of cable used with corrosion-resistant clamps.

B4.3.3. *Fittings.* All cable fittings and terminals shall be watertight at the pressure encountered in use.

B4.3.4. *Lengths.* For each 50 ft of setting 1 ft of extra cable shall be al-

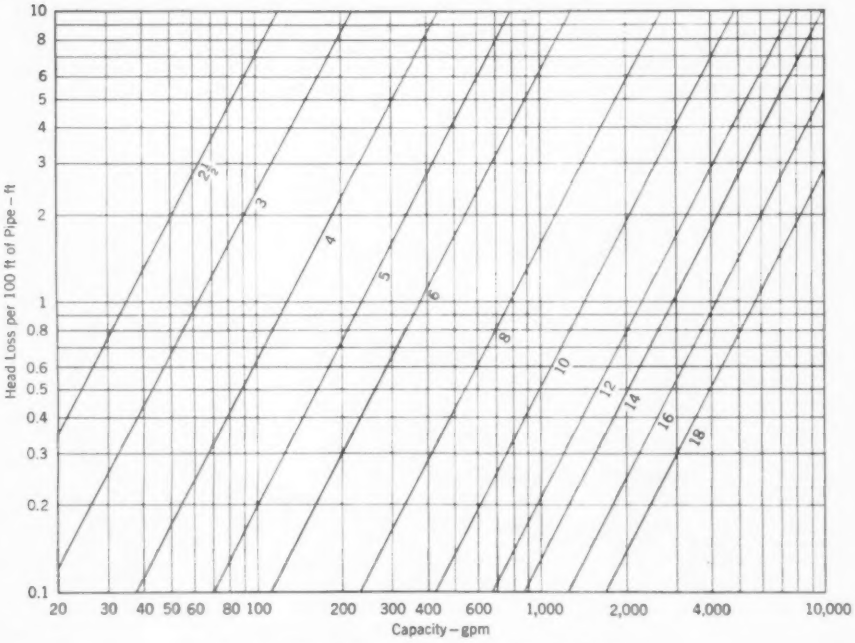

Fig. 9. Head Loss Chart for Standard Pipe

Diagonals are labeled to show nominal diameters (in inches) of discharge column pipe. The calculations used in constructing the chart were based on inside diameters, which are close to the nominal sizes (for example, 10 in. = 10.12 in ID).

lowed to compensate for possible twist or sag of the cable during installation; 10 ft shall be provided beyond the surface plate.

B4.3.5. *Shielding.* The electrical conductors shall be protected by a corrosion-resistant shield where they pass the pump bowls.

Sec. B4.4—Surface Plate

The surface plate (pump base) shall be rigid enough to support the entire weight of the suspended parts when filled with water. The plate shall provide suitable openings for the power cable, well vent, and water level indicator as required. The plate shall also support the discharge connection furnished in a size adequate for the required flow rate and in a pressure series consistent with the surface pressure to be delivered by the pump.

Sec. B4.5—Strainer

A strainer, if furnished, shall have a net inlet area equal to at least three times the impeller inlet area. The maximum unit opening shall not be more than 75 per cent of the minimum opening of the water passage through the bowl or impeller.

Sec. B4.6—Discharge Pipe

The discharge pipe may be furnished in random lengths connected by threaded sleeve couplings. For settings up to 500 ft, the minimum weight shall conform to the values shown in Table 3, and shall have ASA standard tapered pipe threads. For pumps with a total head in excess of 500 ft, each application shall be checked to determine that the strengths of the pipe and threaded joints are adequate. The size shall be such that velocities are not less than 4–5 fps, nor more than 15 fps.

Sec. B4.7—Pump Bowls

Pump bowl castings shall be free of blow holes, sand holes, and other detrimental defects. The bowls shall be capable of withstanding a hydrostatic pressure equal to twice the head at rated capacity or 1½ times the shutoff head, whichever is greater. The bowls may be equipped with replaceable seal rings on the suction side of enclosed impellers.

Sec. B4.8—Impellers

The impellers shall be of the open, semiopen, or enclosed type, statically balanced. They shall be securely fastened to the impeller shaft with keys, taper bushings, locknuts, or setscrews.

Sec. B4.9—Pump-Motor Coupling

The pump-motor coupling shall be of a noncorrosive material and shall be capable of transmitting the total torque and total thrust of the unit in either direction.

Section B5—Engineering Data

Sec. B5.1—Discharge Pipe

Diameters and weights of standard discharge pipe sizes are given in Table 3.

Sec. B5.2—Discharge Friction Loss

The discharge pipe friction loss chart (Fig. 9 or 10) should be used to determine the loss in head due to friction.

Sec. B5.3—Discharge Elbow Head Loss

The discharge elbow head loss chart (Fig. 10) should be used to determine the hydraulic losses in the discharge elbow.

Where extreme accuracy is imperative, actual loss measurements in the discharge elbow to be used—with the correct discharge pipe—should be specified on the bid request by the purchaser.

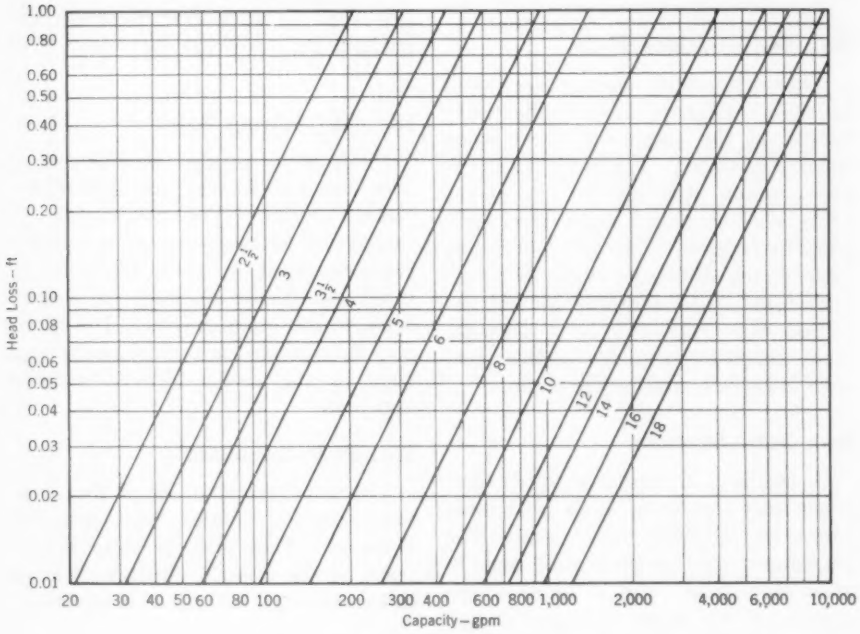

Fig. 10. Head Loss Chart for 90-deg Elbow

Diagonals are labeled to show nominal diameters (in inches) of discharge elbow pipe. The calculations used in constructing the chart were based on inside diameters, which are close to the nominal sizes (for example, 10 in. = 10.12 in. ID).

Section B6—Factory Inspection and Tests

Sec. B6.1—Performance Tests

B6.1.1. The standard procedure for determining the performance of a vertical turbine pump—by making a factory laboratory test of the bowl assembly and then calculating the anticipated field performance—is described below. A performance test will be made only when specified in the purchaser's inquiry and order. The inquiry and order shall specify which of the following are required:

a. Standard running test
b. Witnessed running test
c. Shop inspection
d. Hydrostatic test of bowl assembly.

If other tests are required, the purchaser shall describe them in detail.

B6.1.2. The manufacturer shall notify the purchaser not less than 10 days prior to the date the pump or pumps will be ready for inspection or witness test.

Sec. B6.2—Standard Running Test

B6.2.1. The pump bowl assembly will be operated from zero capacity to the maximum capacity shown on the performance curve submitted with the manufacturer's bid. Readings shall be taken at a minimum of five capacity points, including one point within ± 2 per cent of the design capacity specified on the request for bid.

B6.2.2. At the conclusion of the test, three copies of the test data sheet and the anticipated field performance curve shall be supplied to the purchaser.

Sec. B6.3—Typical Laboratory Test Arrangement

Figure 11 shows a typical laboratory arrangement for the testing of a vertical turbine pump. A test laboratory will normally be constructed to provide favorable suction conditions for pump performance. If the purchaser plans to use the pump under questionable well or sump conditions and wishes the pump to be tested under these exact conditions, complete information should be included in the request for bid. If there is nothing stated in the bid with relation to required well or sump conditions, it shall be assumed that standard laboratory arrangements will be used.

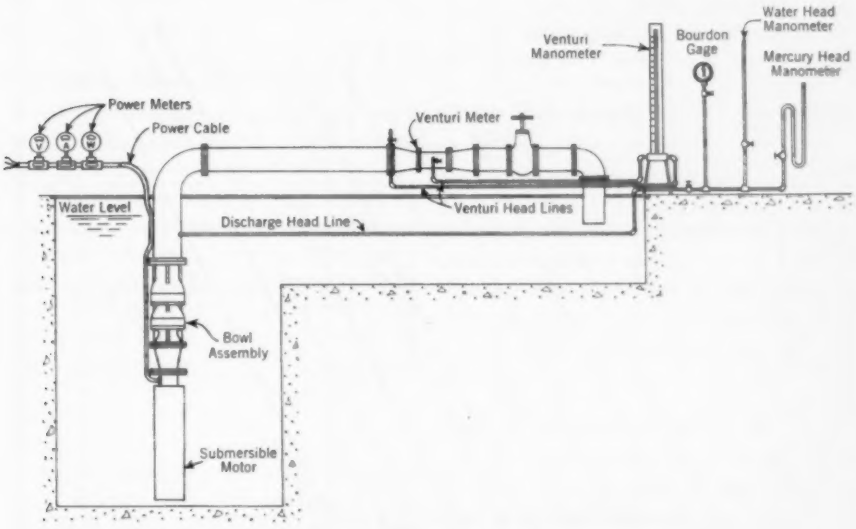

Fig. 11. Typical Laboratory Test Arrangement

Sec. B6.4—Capacity Measurement

The capacity of the pump shall be measured by means of a standard ven-

turi tube, nozzle, orifice plate, or pitot tube traverse. The pump manufacturer shall supply evidence that the capacity-measuring device used has been properly calibrated, that it is in good condition, and that the pressure taps and piping are proper for the instrument being used and are essentially the same as during the calibration. Instruments which have not been calibrated should be geometrically similar to properly calibrated models.

A description of the application of fluid meters is contained in the ASME publication, "Fluid Meters—Their Theory and Application." A detailed description of the various meters and their application is given in Chapter B-2 of that publication, the physical constants and meter coefficients are in-

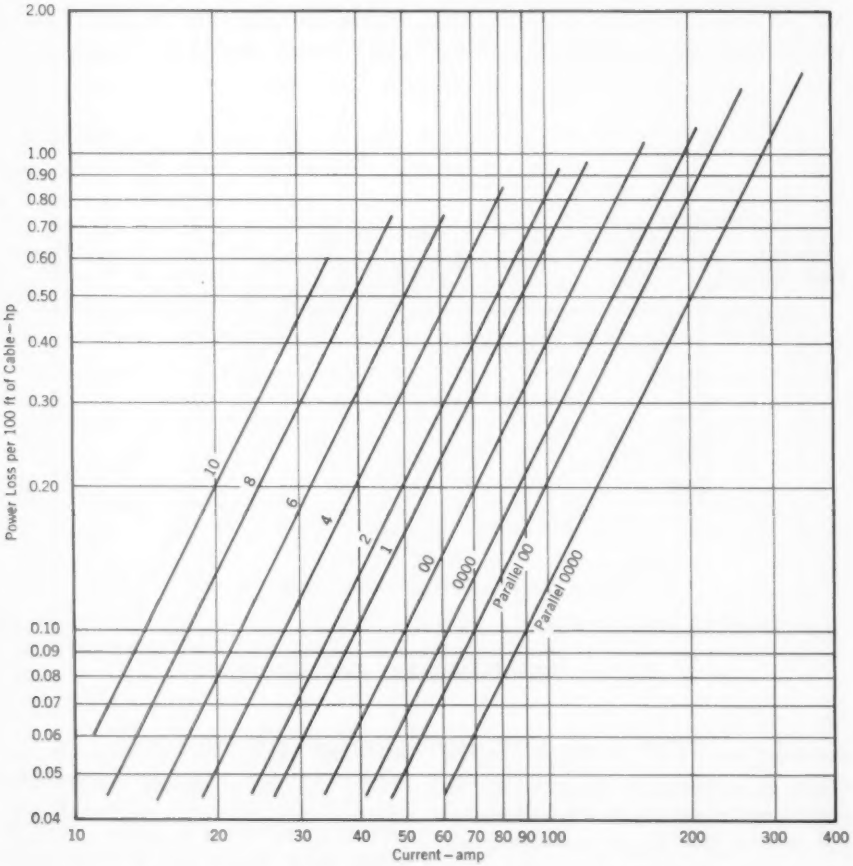

Fig. 12. Power Loss Chart for Three-Conductor Copper Cable

Diagonals are labeled to show sizes (American Wire Gage) of cable conductor wire, and are based on a copper temperature of 60°C and an ambient air temperature of 30°C. Current should not exceed the plotted maximum on any given line. Maximum values must be reduced by a factor of 0.82 for an air temperature of 40°C.

dicated in Section C, and the discharge coefficient tolerance of the various meters are indicated in Chapter C-7.

The surface conditions, size, and length of the pipe preceding the fluid-measuring device are as important as the calibration of the device itself. Thus, piping should be in close conformity with that used when the instrument was calibrated or in accordance with the recommendations by the manufacturer of the fluid-measuring device.

Fluid manometers should be used for measuring the pressure differential across the meter.

Sec. B6.5—Head Measurement

All pump bowl assembly tests shall be made in open sumps, unless otherwise stated in the request for bid.

The pressure tap for head measurement shall be located in the discharge pipe not less than 2 ft above the pump bowl assembly. The pressure tap shall be at right angles to the pipe, free from burrs, and flush with the surface of the discharge pipe. The openings shall be of a diameter from $\frac{1}{8}$ to $\frac{1}{4}$ in. and of a length not less than twice the diameter.

As an alternative method, the pressure tap for head measurement can also be located not less than ten diameters downstream from the discharge elbow of the test pump. (The elbow to be furnished with the pump shall be used.) When the pump head is measured at this point, no deduction for elbow loss need be made in anticipating field performance.

For head measurements of 36 ft or less, only fluid manometers shall be used. For head measurements in excess of 36 ft, calibrated Bourdon or other gages with equivalent accuracy and reliability can be used. All gages shall be calibrated before and after each series of tests.

Sec. B6.6—Velocity Head

The average velocity in the pump column used to determine the velocity head shall be calculated from dimensions obtained by actual measurement of the pipe diameter at the point of pressure measurement.

If the pressure measurement is made downstream from the discharge elbow, the velocity head shall be obtained from actual measurement of the inside diameters of the discharge pipe at the point where the pressure tap is located.

Sec. B6.7—Power Input to Pump Motor

The actual job motor shall be used and the overall submersible-pump efficiency shall be calculated from the measured power input.

Calibrated laboratory type electric meters and transformers shall be used to measure the power input to all motors.

Sec. B6.8—Large-Pump Tests

Sec. A6.9 of Part A (line shaft pumps) of this standard shall also apply to submersible pumps.

Sec. B6.9—Hydrostatic Tests

A standard hydrostatic test on the pump bowl assembly shall be made at $1\frac{1}{2}$ times the shutoff head developed by the pump bowl assembly, or at twice the rated head, whichever is greater.

Sec. B6.10—Recording and Computation of Test Results

B6.10.1. All instrument test readings, as well as corrected readings,

shall be recorded on the test sheet. Complete data concerning the pump, driver, and instrument identification shall also be recorded.

B6.10.2. All test results shall be translated into performance at the anticipated speed of the driver at the design point, according to the following formulas:

$$Q = Q_t \frac{N}{N_t}$$

$$H = H_t \left(\frac{N}{N_t}\right)^2$$

$$\text{bhp} = \text{bhp}_t \left(\frac{N}{N_t}\right)^3$$

in which Q is capacity (gpm), H is head (ft of water), bhp is brake horsepower, N is anticipated operating speed (rpm), and subscript "t" indicates test values.

B6.10.3. The motor power input, in horsepower, is the corrected kilowatt input to motor divided by 0.746.

B6.10.4. The bowl assembly input horsepower to a pump driven by an electric motor is:

$$\frac{\text{kw}}{0.746} E_g$$

kw being the corrected kilowatt input to motor and E_g the motor efficiency from the calibration curve.

B6.10.5. The pump bowl assembly efficiency (E_l) is:

$$\frac{Qh_l}{3{,}960 \times (\text{bhp})}$$

in which Q is the measured capacity (gpm); h_l is the bowl assembly head (ft), including velocity head; and bhp is the brake horsepower to the pump bowl assembly.

B6.10.6. The pump total head (H), in feet, is found by:

$$H = h_l - h_c - h_e$$

in which h_l is the bowl assembly head (ft), from test; h_c is the discharge loss (ft), obtained from Fig. 9 or 10 and based on complete pump setting; and h_e is the discharge elbow loss (ft), from Fig. 10 or actual test.

B6.10.7. The pump input horsepower equals the bowl assembly input plus the cable loss (obtained from Fig. 12) from the surface plate to the motor.

B6.10.8. The overall submersible-pump efficiency (E_p) is found by:

$$E_p = \frac{QH}{3{,}960 \times \text{input hp to motor}}$$

in which the pump total head (H) is obtained from Sec. B6.10.6 and the power input from Sec. B6.10.7.

B6.10.9. The overall efficiency (E) is the pump efficiency (E_p) multiplied by the motor efficiency (E_g).

B6.10.10. The complete pump total head, overall efficiency, and input horsepower should be plotted as ordinates on the same sheet against the capacity as abscissa to show the anticipated field performance of the complete pumps.

Sec. B6.11—Other Tests

For more complete tests, or for tests involving fluids other than water, refer to the ASME "Power Test Code for Centrifugal and Rotary Pumps" as applicable.

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